Prevalence and Characters of Anomalous Coronary Artery from Coronary Magnetic Resonance Angiography

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Background: *Many types of anomalous coronary artery have been reported. Some forms of the anomaly are potentially malignant and can lead to sudden death.*
Objective: *To determine the prevalence and characters of anomalous coronary artery, including the associations of myocardial ischemia.*
Material and Method: *This is a retrospective study. The authors enrolled patients who were referred for cardiac magnetic resonance (CMR) and had magnetic resonance coronary angiography (MRCA) images. Imaging of the coronary arteries was acquired. The presence and patterns of anomalous coronary artery and the presence of myocardial ischemia was recorded. Myocardial perfusion study was also performed in most patients using adenosine stress test.*
Results: *Anomalous coronary artery was detected in 56 out of 3,703 patients (1.51%). There were 24 men (42.9%). Average age was 62.1±15.0 years. Most common type was right coronary artery (RCA) from left coronary cusp. Malignant form was demonstrated in 31 patients (55.4%) and myocardial ischemia was detected in 10 patients (23.3%).*
Conclusion: *Prevalence of anomalous coronary artery was 1.5%. Most common types were RCA from left coronary cusp (30%) and high take-off RCA (30%).*

Keywords: *Anomalous coronary artery, Myocardial ischemia, Sudden death*

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Previous studies have shown that anomalous coronary artery was not uncommon. The prevalence was 0.83% from 10,661 patients who underwent coronary angiography[1]. Most common type was left circumflex artery (LCX) from right aortic sinus. In the past, diagnosis of abnormal origin of coronary artery could be done by coronary angiography. Significant coronary stenosis of the anomalous coronary artery was demonstrated in 71%. Data from a coronary surgery survival study showed that the prevalence of anomalous coronary artery was 0.3%[2]. Most common type involved LCX. Anomalous coronary artery had a greater degree of stenosis than non-anomalous coronary artery. Recently, the easiest way to diagnose is by non-invasive imaging either multidetector computerized tomography (MDCT)[3,4] or magnetic resonance coronary angiography (MRCA)[5,6]. This condition is usually accidentally detected during non-invasive or invasive coronary angiography which has been performed due to clinical indication[1,7]. Among 126,595 patients who underwent coronary angiography at Cleveland Clinic Foundation, anomalous coronary artery was detected in 1.3%[7]. Anomalous coronary artery was considered as benign anomalies in 81%.

Abnormal origin of coronary artery in some patients could lead to life threatening arrhythmia, myocardial ischemia or sudden cardiac death[5]. From an autopsy study of patients with anomalous coronary artery[8], mode of death was cardiac in origin in 59%, 32% of cardiac deaths were sudden death and 45% of

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sudden deaths occurred during exercise. Young patients, especially with anomalous coronary artery running between pulmonary artery and aorta, had an increased risk of sudden cardiac death[8]. Myocardial ischemia can occur when the course of anomalous coronary artery run between the root of aorta and pulmonary artery or right ventricular outflow tract[9]. It is one of the main causes of sudden death in a young population and has been reported to contribute to approximately 13-31% of causes of sudden death in the young[10,11]. The major cause is hypertrophic cardiomyopathy[10,11]. MRCA was considered as an appropriate use of cardiovascular magnetic resonance (CMR)[5,6,12,13].

The primary objective of the present study was to determine the prevalence and characters of abnormal origin of coronary artery as detected by MRCA. The secondary objective of the present study was to describe the prevalence of an abnormal origin of coronary artery with a potentially dangerous course and its association with myocardial ischemia.

Material and Method

Study population

This is a retrospective study. The authors enrolled patients over 18 years of age who were referred for CMR and had MRCA images from 2004 to 2010. MRCA was performed either as the sole indication or as part of the one-stop service of CMR. We excluded patients who could not complete the CMR examination, those with claustrophobia or those who had a prior revascularization. The authors also excluded those with contraindication for CMR such as pacemaker, internal defibrillator or intracranial clip. The present study was approved by the Ethics Committee of Siriraj Hospital.

Magnetic resonance scanning of the coronary arteries

MRCA was performed by a 1.5T Philips Gyroscan ACS-NT scanner (Philips, Best, the Netherlands) with a 5-element cardiac synergy receiver coil. ECG was synchronized during scanning by vectorcardiogram using 3 electrodes placing on the chest wall[14]. Imaging of the coronary arteries was acquired in the mid-diastolic phase of the cardiac cycle. Respiratory motion compensation was performed by navigator technique by placing a navigator on the right hemidiaphragm[15].

A multiplane scan including transverse, coronal and sagittal planes and multislice segmented K-space echo sequence, was employed initially to localize the position of the heart and diaphragm. By the use of the coronal set of images, a 40-slices respiratory gated transverse 3-dimensional segmented echo planar scan was acquired from the base of the heart to the apical area to localize the course of all major coronary arteries. After shimming for fat suppression with a T2-preparation prepulse and a frequency-selective fat saturation prepulse, magnetic resonance imaging of the coronary arteries was performed during free breathing with the 3-dimensional segmented k-space gradient echo sequence (echo time 2.2 msec, repetition time 7.7 msec)[16]. Coronary artery imaging was started with the imaging of the right coronary artery by a double-oblique 3-dimensional volume and 3-point planscan (Fig. 1)[17]. Imaging of the left main, left anterior descending and left circumflex coronary artery was then performed by a double-oblique transverse 3-dimensional volume with anterior-posterior and right-left angulation. The 3-dimensional volumes were reconstructed to 20 slices with a slice thickness of 1.5 mm, a field of view 360 mm, and a 512x360 matrix which yielded a voxel size of 0.7x1.0 mm.

Among those who underwent CMR perfusion study, first-pass perfusion study was performed by an injection of 0.05 mmol/kg of gadolinium (Magnevist, Schering AG, Berlin, Germany) immediately after 4-minute infusion of 0.056 mg/kg of adenosine. During adenosine infusion, blood pressure and oxygen saturation (by pulse oximetry) was measured once per minute and an ECG rhythm was continuously monitored.

Analysis of MRCA

Images of the MRCA were analyzed by the consensus of two experienced interpreters who were blinded to the patient data. The presence and patterns of anomalous coronary artery according to a previous recommendation[18] was recorded. MRCA was also interpreted for the possibility of having atherosclerotic coronary artery disease (CAD) by reading either as significant CAD (if there was a remarkable localized attenuation of the signal of the coronary lumen) or as

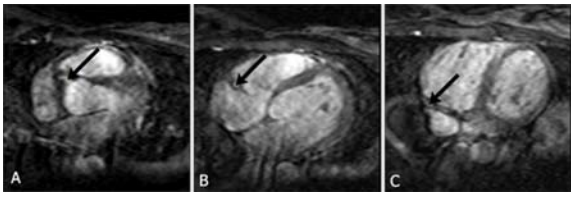

Fig. 1 Three-point plan scan. Three points was marked at proximal (A), mid (B) and distal part (C) of the RCA (arrows) during the process for the acquisition plane of the RCA.

no evidence of significant CAD. Anomalous coronary artery was considered as malignant form when the anomalous coronary arteries run in the interarterial course or acute angle take of[19].

For those who underwent CMR perfusion study, myocardial perfusion defect was defined as a perfusion delay that persisted for at least 5 consecutive phases in at least 1 myocardial segment during the peak myocardial enhancement. If the defect was present before contrast injection, it should be considered an artifact.

Statistical analysis

Continuous data were described as mean and standard deviation (SD). Categorical data were described as number and percentages. Comparison of continuous data was performed by the student t-test for independent variables and comparison of categorical data were performed by the Chi-square test or Fisher's exact test wherever appropriate. A p-value of <0.05 was considered statistically significant.

Results

MRCA was performed in 3,703 patients. Abnormal origin of coronary artery was detected in 56 patients who accounted for 1.51%. Indications for CMR were for the assessment of myocardial ischemia and/or myocardial viability. MRCA in patients with anomalous coronary artery was the sole referral indication in 12 patients (21.4%) and was performed as part of one-stop service on 44 patients (78.6%). Anomalous origin was from contralateral coronary artery in 26 cases (46.4%). Baseline characteristics of patients with and without anomalous origin from contralateral coronary artery are shown in Table 1. There was no significant difference of baseline characteristics and CMR findings between the two groups. Chest pain and dyspnea on exertion were noted in 44.6% and 48.2%, respectively. No patient had an episode of syncope. Characters of anomalous coronary artery are described in Table 2.

Table 1. Baseline characteristics of patients with anomalous coronary artery with and without abnormal origin from contralateral coronary sinus. Variables are presented with count (percentages) or mean ± SD

Variables	Number (%) or mean ± SD			p-value
	All patients	ACA from CCS (n = 26)	Other ACA (n = 30)	
Male	24 (42.9)	11 (42.3)	13 (43.3)	0.938
Age	62.1±15.0	60.2±15.4	63.7±14.8	0.394
Smoker	8 (14.3)	3 (10.0)	5 (19.2)	0.325
Hypercholesterolemia	23 (41.1)	8 (30.8)	15 (50.0)	0.145
Diabetes mellitus	16 (28.6)	6 (23.1)	10 (33.3)	0.397
Hypertension	31 (55.4)	13 (50.0)	18 (60.0)	0.453
Angina	25 (44.6)	11 (42.3)	14 (46.7)	0.743
Dyspnea	27 (48.2)	13 (50.0)	14 (46.7)	0.803
Medications				
Beta-blocker	16 (28.6)	6 (23.1)	10 (33.3)	0.397
Calcium antagonist	7 (12.5)	2 (7.7)	5 (16.7)	0.311
Nitrate	9 (16.1)	3 (11.5)	6 (20.0)	0.390
Antiplatelet	23 (41.1)	9 (34.6)	14 (46.7)	0.361
ACEI or ARB	15 (26.8)	5 (19.2)	10 (33.3)	0.235
Statin	18 (32.1)	6 (23.1)	12 (40.0)	0.176
CMR variables				
LVEDV	123.8±48.3	126.1±53.6	121.7±43.9	0.742
LVESV	44.1±36.5	41.8±30.4	46.1±41.6	0.662
LVMASS	93.4±44.5	93.0±38.3	95.7±50.1	0.823
LVEF	67.6±13.3	69.5±11.6	66.0±14.7	0,338

ACA = anomalous coronary artery; CCS = contralateral coronary sinus; ACEI = angiotensin converting enzyme inhibitor; ARB = angiotensin receptor blocker; CMR = cardiac magnetic resonance; LVEDV = left ventricular end-diastolic volume; LVESV = left ventricular end-systolic volume; LVMASS = left ventricular mass; LVEF = left ventricular ejection fraction

The most common form of abnormal origin of coronary artery was RCA from left coronary sinus that was demonstrated in 17 patients (30.4%). Potentially malignant types of abnormal origin of coronary artery is demonstrated in 31 patients (55.4%), which consisted of inter-arterial course of the anomalous coronary arteries in 25 patients (44.6%) and slit like ostium in 23 patients (41.1%). Seventeen cases (30.4%) had both inter-arterial course and slit like ostium. Table 3 showed that a malignant form of anomalous coronary artery was associated with an anomaly of origin and course of the anomalous coronary artery. Fig. 2-5 display common forms of abnormal origin of coronary artery; RCA from left coronary sinus, anterior and inter-arterial course (Fig. 2), LCX from right coronary sinus, posterior course (Fig. 3), high take-off RCA (Fig. 4), and separate origin of LAD and LCX (Fig. 5).

Atherosclerotic CAD was detected in 12 patients (21.4%). Myocardial perfusion study was performed in 43 patients (76.8%). Myocardial ischemia was demonstrated in 10 patients (23.3%). All patients with myocardial ischemia also had atherosclerotic CAD

Table 2. Description of patterns of anomalous coronary artery. Variables are presented with count and percentages

Various patterns of ACA	Number (%)
A. Origin and course anomalies of the central coronary segments	27 (48.2)
RCA from LCS, anterior or interarterial course	17 (30.4)
LCA from RCS, interarterial course	1 (1.8)
LCA from pulmonary artery, posterior course	1 (1.8)
LAD from RCS, anterior course	1 (1.8)
LCX from RCS, posterior course	6 (10.7)
3 origins from RCS	1 (1.8)
B. Anomaly of only coronary origins	24 (42.9)
High take-off RCA	17 (30.4)
Separate origin of LAD and LCX from LCS	7 (12.5)
C. Origin and courses of peripheral coronary segments	2 (3.6)
Anomalies of peripheral branches of LCA	2 (3.6)
D. Arteriovenous coronary fistula	3 (5.4)
RCA fistula	2 (3.6)
LCA fistula	1 (1.8)

ACA = anomalous coronary artery; RCA = right coronary artery; LCS = left coronary sinus; LCA = left coronary artery; RCS = right coronary sinus; LAD = left anterior descending artery; LCX = left circumflex artery

Table 3. Associations of malignant form of anomalous coronary artery with the pattern of anomaly and myocardial ischemia. Variables are presented with count (percentages)

	Number (%)		p-value
	Malignant form (n = 31)	Non-malignant form (n = 25)	
Characters of anomalous coronary anomaly			<0.001
A. Origin and course anomalies of the central coronary segments	24 (77.4)	3 (12.0)	
B. Anomaly of only coronary origins	7 (22.6)	17 (68.0)	
C. Origin and courses of peripheral coronary segments	0 (0)	2 (8.0)	
D. Arteriovenous coronary fistula	0 (0)	3 (12.0)	
Anomalous coronary anomaly from contralateral coronary sinus	24 (77.4)	2 (8.0)	<0.001
Myocardial ischemia*	2/23 (8.7)	8/20 (40.0)	0.028
Atherosclerotic CAD	4 (12.9)	8 (32.0)	0.083

CAD = coronary artery disease

* Number for denominator is included since the test was not performed in every patient

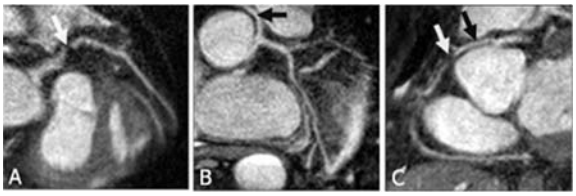

Fig. 2 RCA from left coronary sinus, anterior and interarterial course can be visualized in the transverse (B) and RCA view (C) (black arrows). A; LAD view, B; transverse view, and RCA view (C). This patient also had significant stenosis of proximal LAD and proximal RCX (white arrows).

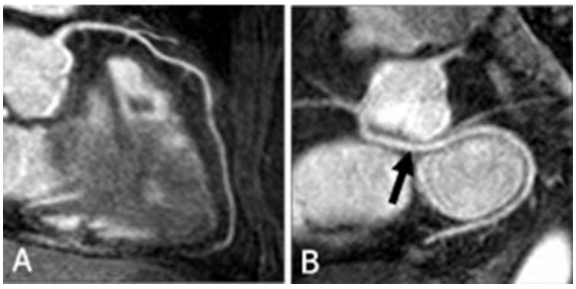

Fig. 3 LCX from right coronary sinus, posterior course can be visualized in the LCX view (arrow). A; LAD view, B; LCX view.

from coronary MRA. Among 10 patients with myocardial ischemia, 5 patients had high take off, of RCA, 4 had separate origin of LAD and LCX, and 1 had RCA from left coronary sinus. Two out of 10 had double vessel disease (LAD and RCA in 1 and LAD and LCX in another case), 8 had single vessel disease (LAD in 6 cases, LCX in 1 case and RCA in 1 case). Myocardial ischemia could not be explained by the anomalous coronary artery since all patients with myocardial ischemia had a non-malignant course of the anomalous coronary artery.

Discussion

The results of the present study showed that the prevalence of abnormal origin of coronary artery was 1.5% of patients who were referred for CMR for clinical indication. The common forms of abnormal origin of coronary artery were anomalous RCA from left coronary sinus.

Prevalence of anomalous coronary artery that has been reported varied between 0.3 and 1.3%[1,2,7]. The variation may depend on the present study population and the method for the detection of anomalous coronary artery. The prevalence may be low if screening is done in asymptomatic population but

Fig. 4 High take-off RCA in the RCA view (arrow).

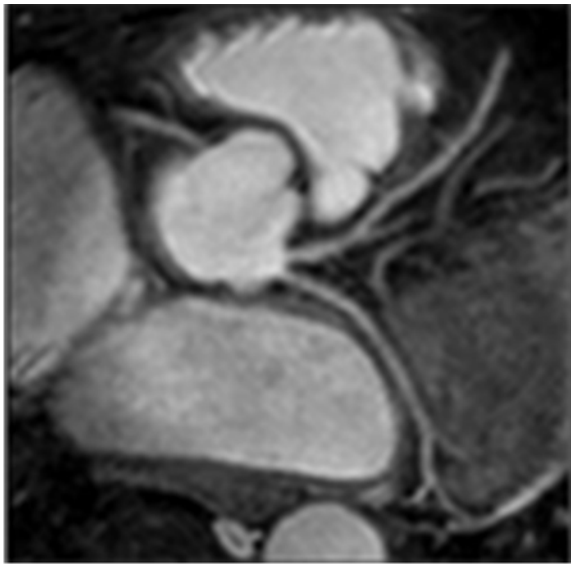

Fig. 5 Separate origin of the LAD and LCX from left coronary sinus in the transverse view.

may be relatively high in symptomatic population[8]. Prevalence in the present study was 1.5%. The populations in the present study were patients who were referred for CMR for clinical indication.

Anomalous coronary artery from contralateral coronary sinus may be associated with a malignant course which is related to an increase risk for sudden cardiac death[20,21]. The present study demonstrated that the most common form of anomalous coronary

artery was RCA from left coronary sinus which is different from previous reports which demonstrated that anomaly of LCX was the most common form[1,2]. Another common form of anomalous coronary artery from contralateral coronary sinus was LCX from right coronary sinus. There was no significant difference in baseline characteristics and CMR findings between patients with anomalous coronary artery from contralateral CS and those with other forms of anomalous coronary artery. The present study also showed that 77% of patients with anomalous coronary artery from contralateral coronary sinus were associated with malignant forms defined as inter-arterial course or slit like appearance of coronary ostium. Previous studies have shown that anomalous coronary artery from contralateral coronary sinus especially RCA from left coronary sinus, had an increased risk of sudden cardiac death[20,21].

Management of patients with anomalous coronary artery may depend on age of presentation, symptoms and the presence of myocardial ischemia[8,20,21]. Surgical correction may be needed if patients present at the early age, are symptomatic or had evidence of myocardial ischemia by non-invasive test[9,21,22]. Surgical risk has also been taken into consideration. The present study populations were patients who were referred for CMR for clinical indication. Therefore, populations in the present study were older and more symptomatic. The prevalence of myocardial ischemia and atherosclerotic disease was also higher than previous reports[3,18] that use computerized tomography for diagnosis, but was similar to a previous report using coronary angiography for diagnosis[23]. However, myocardial ischemia in our study was related to atherosclerotic CAD which is different from the mechanism of myocardial ischemia related to anomalous coronary artery in previous reports that were related to compression of the anomalous coronary artery due to compression of the arteries with inter-arterial course[24,25]. In contrast to atherosclerotic CAD for which invasive coronary angiography is the gold standard for the diagnosis, the yield for the diagnosis of anomalous coronary artery by non-invasive coronary angiography such as CT scan or MRCA is higher than for invasive coronary angiography. In fact, it has been shown that invasive coronary angiography can give diagnosis of anomalous coronary artery in only 55% of cases[21].

Conclusion

In conclusion, the prevalence of anomalous coronary artery was 1.5%. Most common types were RCA from left coronary sinus (30%) and high take-off RCA (30%). Malignant form was shown in 31 cases (55.4%).

What is already known on this topic?

Anomalous coronary artery may lead to sudden cardiac death in the young.

What this study adds?

This study showed the prevalence and pattern of anomalous coronary artery in Thai population. This study also described the prevalence of malignant pattern of anomalous coronary artery and its relation to myocardial ischemia.

Potential conflicts of interest

None.

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ความชุกและรูปแบบของภาวะหลอดเลือดหัวใจผิดปกติแต่กำเนิด (anomalous coronary artery) จากการตรวจหัวใจด้วยสนามแม่เหล็ก

รุ่งโรจน์ กฤตยพงษ์, อดิศักดิ์ มณีไสย, ไพรัช สายวิรุณพร, สุภาพร นาคเย็น, ประจักษ์ ธนาพิบูลย์ผล, อาทิตย์ ยินดีงาม

ภูมิหลัง: ภาวะ anomalous coronary artery เป็นสาเหตุเหนึ่งของ sudden death ได้

วัตถุประสงค์: เพื่อศึกษาความชุกและรูปแบบของ anomalous coronary artery และความสัมพันธ์กับภาวะหัวใจขาดเลือด

วัสดุและวิธีการ: การศึกษานี้เป็นการศึกษาย้อนหลัง ได้ศึกษาผู้ป่วยที่ได้รับการตรวจ magnetic resonance coronary angiography การตรวจภาพของ coronary artery ใช้วิธีมาตรฐาน ผู้ป่วยส่วนใหญ่ได้รับการตรวจ myocardial perfusion ด้วยวิธี adenosine stress test ผู้วิจัยทำการบันทึกการตรวจภาพและรูปแบบของภาวะ anomalous coronary artery และการตรวจภาพภาวะหัวใจขาดเลือด

ผลการศึกษา: ตรวจพบภาวะ anomalous coronary artery 56 ราย จาก 3,703 ราย (1.51%) เป็นเพศชาย 24 ราย (42.9%) อายุเฉลี่ย 62.1±15.0 ปี รูปแบบที่พบบ่อยที่สุดคือหลอดเลือดหัวใจด้านขวาออกจาก aortic cusp ด้านซ้ายพบ 31 ราย (55.4%) พบหัวใจขาดเลือดร่วมด้วย 10 ราย (23.3%)

สรุป: ความชุกของภาวะ anomalous coronary artery เป็น 1.51% รูปแบบที่พบบ่อยที่สุดเป็นหลอดเลือดหัวใจด้านขวาออกจาก aortic cusp ด้านซ้าย