Assessment of Clinical Features and Morphological Characteristics of Myocardial Bridging Involving the Left Circumflex Artery Using Coronary Computed Tomography Angiography

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Research Article

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Abstract

Purpose

This retrospective study aimed to investigate the clinical features and morphological characteristics of myocardial bridging involving the left circumflex artery and its branches using coronary computed tomography angiography.

Methods

We enrolled 23 patients (mean age: 55.65 ± 13.28 years) with myocardial bridging of the left circumflex artery between January 1, 2014 and July 31, 2020. All patients underwent coronary computed tomography angiography and electrocardiography. The morphology, clinical findings, and coronary computed tomography angiography -derived fractional flow reserve were compared for patients with myocardial bridging of a single left circumflex artery ($n = 23$), right coronary artery ($n = 10$), and left anterior descending artery ($n = 23$).

Results

Myocardial bridging of the left circumflex artery were more commonly superficial (superficial myocardial bridging: 22 vs. deep myocardial bridging: 1) while bridging in the left anterior descending artery was mostly located in the middle segment (91%, 21/23), and bridging in the left circumflex artery was mostly located on the distal-segment or obtuse marginal branch (87%, 20/23). The 95% confidence interval of myocardial bridging thickness, myocardial bridging length, arterial diameter in systole and diastole period of the myocardial bridging of the proximal segment was: 0.24 (0.05, 0.43), 2.88 (2.32, 3.42), 1.67 (1.47, 1.87), and 1.74 (1.54, 1.95), respectively. 95% confidence interval of computed tomography-derived fractional flow reserve in the proximal and distal segments of bridging were 0.96 (0.96, 0.97) and 0.93 (0.92, 0.94), respectively. All heart dominance showed right coronary dominance (73.91%, 17/23) or co-dominance (26.09%, 6/23).

Conclusions

All patients with bridging segments in the left circumflex artery have right coronary dominant or co-dominant hearts. Bridging of the left circumflex artery is mostly long and located in the distal segment. Computed tomography-derived fractional flow reserve showed a low value in diagnosing myocardial ischemia resulting from myocardial bridging of the left circumflex artery.

Introduction

Myocardial bridging (MB) is a congenital anomalous coronary disease that is defined as a segment of the coronary artery covered by myocardial fibers. MB is generally considered to be a benign disease as most patients are asymptomatic. However, some researchers have recently identified that MB can cause angina, coronary syndrome, and severe cardiac events [1–4]. Most MBs involve the left anterior descending (LAD) artery, followed by the left circumflex (LCX) artery, right coronary artery (RCA), and other small branches, such as the diagonal artery, ramus intermedius artery, and obtuse marginal branch (OM) artery [5, 6]. Multiple investigations have reported on the morphology and clinical features of MB located on the LAD artery; however, a few case reports have described symptomatic cases in which MB involved the LCX artery [7–14], and almost all of these patients underwent conventional coronary angiography. No studies describe the clinical features and morphological characteristics of bridges in the LCX artery; especially the change of hemodynamics in the bridging segment. Therefore, this study aimed to assess the value of clinical findings, morphological characteristics using coronal computed tomography angiography (CCTA), and hemodynamic changes in MB of the LCX artery using computed tomography-derived fractional flow reserve (CT-FFR) and the CCTA.

Methods

Population study

This retrospective study included 8,375 patients with MB, who were diagnosed using CCTA between January 1, 2014, and July 31, 2020, from the Picture Archiving and Communication System at our center. We selected 100 patients with bridging of the LCX artery. Among them, only patients with isolated MB involving the LCX artery and its branches were enrolled in the study. The exclusion criteria were as follows: 1) MB associated with atherosclerosis and other cardiovascular diseases, 2) MB associated with pulmonary artery disease, 3) MB associated with structural heart disease, 4) Poor quality CCTA images that affect the diagnosis, 5) MB associated with abnormal coronary artery origin, 6) MB involving both LCX and non-LCX coronary artery branches. A flow chart of the data filtering process is illustrated in Fig. 1. Finally, 17 patients

with MB of the LCX artery, 5 patients with MB of the OM branches, and 1 patient with MB of both the LCX artery and OM branches were included in the study. In addition, 23 cases of isolated MB of the LAD artery were selected randomly according to the age- and sex-matched methods, while 10 patients with MB of the RCA were included in the control group. Duplicate cases were not included, and information regarding general characteristics like the name, age, and sex of the patient was kept hidden by the author (PP. W) to protect patient's privacy. This study has been approved by the hospital ethics committee.

The length, depth, and location of the MB along with the electrocardiogram (ECG), CT-FFR of the proximal and distal segments of the bridging, and other clinical findings were analyzed. The MB length was defined as the curve distance from the start to the end of the MBs. The MB depth was defined as the maximum thickness of the myocardial fibers covering the tunnel coronary artery. Superficial and deep MBs were defined as an MB depth of < 2 mm and > 2mm, respectively. To explore the relationship between heart dominance and the location of MB, we retrospectively enrolled 100 patients out of 8,375 patients with MB of the LCX artery and its branches, including those associated with other cardiovascular diseases.

Ct Protocols

All imaging data were acquired using GE Revolution CT (GE Healthcare, Little Chalfont, UK). The nurses adhered to the standard operating procedures, including embedding indwelling needles in the vein and imparting breathing training, before scanning. The scanning parameters were set as follows: 1) The tube voltage and tube currents were 120 KV and 34 mA, respectively. 2) The tube thickness was set at 1.25 mm with a 2 mm internal diameter. CCTA is a noninvasive imaging modality that can precisely delineate the spatial relationship of the coronary artery anatomy. During CCTA imaging acquisition, patients were asked to hold their breath. Simultaneously, iodine contrast agent and normal saline, according to the patient's weight, were injected through two high-pressure syringes at a speed of 5.0 ml/s. The bolus tracking technique was used to detect the threshold of the aortic root. CCTA imaging was started 5s after an attenuation threshold of > 100 Hounsfield units .

Imaging Analysis

After imaging acquisition by revolution CT, CCTA imaging reconstruction was performed using a CardIQ Xpress (GE Healthcare, USA). Three imaging modality data were derived from the CCTA: maximum intensity projection, oblique imaging, and volume rendering ; all three parameters showed positive values due to the relationship between the myocardium and the coronary artery. Additionally, coronary stenosis and plaques could be delineated by viewing the coronary artery lumen using axial imaging. CCTA imaging is usually reconstructed in 75% of the phase of the cardiac cycle, which is at systole; during this period, the lumen of the coronary artery is clearly visible. The CT-FFR values were measured using Shukun-FFR V1.0 (Shukun, China). The CT-FFR value is an important parameter for diagnosing myocardial ischemia. A value of CT-FFR > 0.8 was considered to be no myocardial ischemia, $0.75 < \text{CT-FFR} < 0.8$ was considered to have no clinical significance, and CT-FFR < 0.75 was considered to be myocardial ischemia; the smaller the value, the greater the possibility of myocardial ischemia.

Statistical analysis

Statistical analyses were performed using the IBM commercial software SPSS (Version 25.0, American). Age, MB length, and MB depth are presented as mean $\pm$ SD. The CT-FFR value and artery diameter in the systole and diastole periods are presented as mean (95% confidence interval). The number of dominant coronary artery types and the number of patients with MB according to location were statistically calculated as percentages. Statistical significance was set at $p < 0.05$.

Results

Patients' demographics

A total of 100 patients with MB of the LCX artery were selected out of the 8375 patients with MB. The demographics are illustrated in Table 1. The mean age of those 100 patients was 57.43 ± 13.67 years. The number of males and females were 51 and 49, respectively. Among the 100 patients, 49 had isolated MB of the LCX artery, but out of 49 patients, 29 were associated with lesion of the coronary artery. Otherwise, the number of right coronary dominance and balance dominance were 80 and 20, respectively; while no left coronary dominance existed in this group. Regarding clinical characteristics, 53 out of 100 patients had a typical chest pain or chest discomfort, 30 had hypertension, and 28 had coronary atherosclerosis.

Table 1
Clinical characteristics of included LCX and OM MB patients

	LCX MB (n = 17)	OM MB (n = 5)
Age (mean $\pm$ SD)	52.22 $\pm$ 12.17	68 $\pm$ 8.67
Sex (male)	6 (35.29%)	0
MB length (mean $\pm$ SD)	2.82(2.20–3.43)	3.10(1.15–5.05)
MB depth (mean $\pm$ SD)	0.24(0–0.49)	0.24(0.19,0.28)
CT-FFR in proximal to MB	0.96 (0.96–0.97)	0.96 (0.96–0.97)
CT-FFR in distal to MB	0.93 (0.92–0.94)	0.93(0.91–0.96)
Arrhythmia	3 (17.64%)	0
hypertension	3 (17.64%)	2 (40%)
Chest pain and chest discomfort	6 (35.29%)	1 (20%)
ECG abnormal	9 (47.37%)	3 (60%)
Right Coronary dominance	12 (70.59%)	5 (100%)
Left Coronary dominance	0	0
Co-dominant coronary	6 (29.41%)	0
Deep MB	1 (5.88%)	0
Superficial MB	16 (94.12%)	5 (100%)

To explore the demographics and clinical features of isolated MB of the LCX artery, a total of 23 patients (mean age, 55.65 $\pm$ 13.28 years) with bridging of the LCX artery were enrolled for the study. Among them, 17 patients with MB of the LCX artery, 5 with MB of the OM artery, and 1 with bridging of both the LCX and OM arteries were enrolled in the study. Further, a patient associated with the abnormal arising LCX artery from the right sinus and bridging of the OM. In addition, 23 patients (mean age: 55.65 $\pm$ 13.28 years) with MB of the LAD artery and 10 patients (mean age: 53.10 $\pm$ 11.06 years) with MB of the right coronary artery were selected in the control group. The demographics are illustrated in Table 2. The number of patients with chest pain or chest discomfort were 18 (18/23, 78.26%), 17 (17/23, 73.91%), and 7 (7/10, 70%), respectively. There is no significant difference of the number of chest discomfort between the three groups. The Left coronary artery dominance was not observed in these groups. The 95% CI of the thickness and length of bridging segment in three groups were: (LCX: 0.24 [0.05, 0.43] vs. LAD: 1.34 [-0.53, 3.21] vs. RCA 0.64 [0.23, 1.05]) and (LCX: 2.88 [2.32, 3.42] vs. LAD: 2.19 [1.68, 2.69] vs. RCA 2.57 [1.55, 3.60]), respectively. The 95% CI of CT-FFR in the proximal and distal segments of bridging of the three groups were: (LCX: 0.96 [0.96, 0.97] vs. LAD: 0.93 [0.91, 0.95] vs. RCA 0.95 [0.92, 0.97]) and (LCX: 0.93 [0.92, 0.94] vs. LAD: 0.89 [0.86, 0.92] vs. RCA 0.89 [0.87, 0.93]), respectively. In addition, abnormal ECG findings were present in more than half of the patients with MB (LAD artery MB, 60.87% [14/23] vs. LCX artery MB, 52.17% [12/23] vs. RCA MB, 50% [5/10]). MB in the LAD and RCA are mostly located in the middle segments (21/23 vs 7/10); but MB in the LCX artery is mostly located in the distal segments (22/23).

Table 2
Characteristics of MB in the LCX, RCA, and LAD

		LAD MB(n = 23)	LCX MB(n = 23, 24 bridging segments)	RCA MB (n = 10)	p value
age		55.65 ± 12.97	55.65 ± 12.97	54.1 ± 10.49	P > 0.05
Sex (male: female)		6:17	6:17	8:2	
hypertension		1	5	1	
Chest pain or chest discomfort		73.91% (17/23)	78.26% (18/23)	70% (7/10)	P > 0.05
Coronary dominant	left	0	0	0	
	balance	0	6	2	
	right	23	17	8	
ECG abnormal (n)		60.87% (14/23)	52.17% (12/23)	50% (5/10)	
MB location	proximal	0	1	2	
	middle	23	1	7	<i>P < 0.001</i>
	distal	2	22	1	<i>P < 0.001</i>
MB type	deep	2	1	0	
	superficial	21	23	10	<i>P > 0.05</i>

More importantly, we demonstrated the CCTA performance of different types of MB (Fig. 2 to Fig. 5). Through VR and oblique reconstruction, we clearly observed the course of the coronary artery, its relationship with myocardial tissue, and the condition inside the coronary lumen, such as the presence of plaque, stenosis, and/or obstruction.

Discussion

Our study is the first study to investigate the clinical features and morphological characteristics of patients with MB of the LCX artery. We found that MB of the LCX artery was mostly located on the distal segment, and mostly MB of the LCX artery is superficial, long bridging, and non-left coronary dominant. Patients with bridging in the LCX artery are usually associated with chest discomfort and abnormal ECG, but with a normal CT-FFR value, which is different from the study results [15]. Coronary atherosclerosis did not occur in patients with MB of the LCX artery.

MB was discovered by Reyman through an autopsy in 1737 and was first described by Geringer in 1951 through coronary angiography [16, 17]. It has been proved to have a systole “Milk-effect” phenomenon and can result in a change in the hemodynamics of the bridging segment artery [18]. In 1960, Portsman and Iwig described it angiographically as a transient narrowing of the coronary artery during systole [19]. Furthermore, MB can lead to severe cardiac events such as myocardial ischemia, angina, myocardial infarction, and sudden death.

The LCX artery is one of the three major branches of the coronary artery, and it mainly supplies the left ventricular lateral wall and posterior wall of the heart. However, very few original papers mentioned MB of the LCX artery, but did not describe it in detail [20–26]. Furthermore, several researchers have reported case reports stating the characteristics of MB of the LCX artery [7–14]. Even though most MBs are considered congenital and asymptomatic, most cases have reported that patients with MB of the LCX artery experienced severe and chronic chest pain [7–9, 11–14]. In 2005, Gunduz et al. first described a case of myocardial infarction in the first OM of the LCX artery [9]. Aksoy et al. reported that asymptomatic MB cases showed 100% systolic narrowing and incidentally presented with acute coronary syndrome [11]. A few reports on MB involving the LCX artery are shown in Table 3. MB involving the LCX artery may also be associated with changes in the ECG (7,8,10,12,13, angina [8], acute coronary syndrome, and severe cardiac events [12]. Published case reports suggest that ST-segment changes are the main changes in patients with MB of the LCX artery [8, 10, 13].

Table 3
Summarizing publishes of MB of LCX

	Study year	Study type	Imaging examination methods	age	sex	hypertensive	Smoking	Clinical findings	ECG	Other characteristics
1	Grag et al 2000[5]	Case report	Coronary angiography	35	male	no	yes	Atypical chest pain for 17 years	R wave poor progression and T waves inversion	unknown
2	Okmen et al 2002[6]	case report	Coronary angiography	45	male	yes	yes	Chest pain to the left shoulder on exertion for the last 4 months	ST-segment depression	exercise-induced angina pectoris;
3	Gunduz et al 2005[7]	letter to the editor	Coronary angiography & echocardiographic	54	male	no	unknown	chest pain and progressive dyspnea	unknown	Myocardial bridging in the obtuse marginal branch of LCX
4	Tuncer et al 2008[8]	case report	Coronary angiography	63	male	no	no	Chest pain radiating to the left shoulder	ST-segment changes	A significant systolic narrowing on the mid-LCX
5	Peters S 2019[9]	letter to the editor	Coronary angiography	38	female	unknown	unknown	Chest pain	unknown	unknown
6	Aksoy et al 2017[10]	case report	Coronary angiography	62	male	no	yes	Severe, squeezing chest pain	T wave inversion and R wave progression	unknown
7	Ibarrola et al 2019[11]	case report	Coronary CTA	54	female	unknown	unknown	unknown	ST depression	LCX arising from right sinus ostium
8	Kiris et al 2016[12]	Case report	Coronary CTA	46	male	unknown	unknown	With recurrent retrosternal chest pain of 3 months duration	unknown	MB in the LAD, ramus intermediate, and first OM
Note: MB: myocardial bridging; LAD: left anterior descending artery; LCX: left circumflex artery; OM: obtuse marginal branch; ECG: electrocardiogram; CCTA: coronary computed tomography angiography.										

Few studies have pointed out that MB located on the proximal segment may easily prolong the development of coronary atherosclerosis and hemodynamic changes [15, 27]. Therefore, knowing the position of bridging in the coronary artery is vital, as it provides diagnostic information that can guide management of the condition. In this study, the MB of the LCX artery was mostly located at the distal segment and was not associated with atherosclerosis. A study [5] has pointed out that the overall average MB length was 2.02 cm. However, in this study, the 95% CI of the length of bridging segment in LCX, LAD and RCA groups were, LCX: 2.88 (2.32, 3.42), 2.19 (1.68, 2.69), 2.57 (1.55, 3.60). In this study, we observed that bridging segments in the LCX artery were longer than that in the other arterial branches.

In this study, almost 70% patients with MB were associated with chest pain or discomfort for a long time, but all CT-FFRs were normal even in patients with chest discomfort or chest pain. The 95% CI of CT-FFR in the proximal segment of bridging of the three groups were, LCX: 0.96 (0.96, 0.97), LAD: 0.93 (0.91, 0.95), and RCA 0.95 (0.92, 0.97), respectively. Further, the 95% CI of CT-FFR in the distal segment of bridging of the three groups were LCX: 0.93 (0.92, 0.94), LAD: 0.89 (0.86, 0.92), RCA 0.89 (0.87, 0.93), respectively; with no significant difference between the three groups. This result may be related to the data inclusion criterion which only enrolled patients with isolated MB. Moreover, in most patients, MB of the superficial type was present.

However, most patients presented with chest pain and abnormal ECG was observed even in patients with superficial and normal hemodynamics, which is independent of the location of the MB. In this study, abnormal ECG findings were present in more than half of the patients with MB (LAD artery MB, 60.87% [14/23] vs. LCX artery MB, 52.17% [12/23] vs. RCA MB, 50% [5/10]).

Coronary artery dominance depends on the origin of the posterior descending artery, which supplies blood to the posterior portion of the interventricular septum [28–30]. There are three types of coronary artery dominance: right, co-dominant, and left. The right coronary dominant heart was defined as the posterolateral portion arising from the right coronary artery, and the left coronary dominant heart was defined as the posterior descending artery arising from the LCX artery [29]. It has been found that about 80–85% of the coronary arteries present a right-dominant pattern [31]. The coronary artery tree with different coronary artery dominance was reconstructed based on CCTA, as shown in Fig. 6. All the enrolled patients were found to have right dominant or co-dominant hearts, and no left dominant hearts were found. There are two reasons for this phenomenon. First, the right dominant and co-dominant heart commonly exist in the human heart, and MB involving the LCX artery is a rare cardiovascular disease. Second, in the left dominant heart, the LCX artery is the main coronary artery supplying the interventricular septum. Therefore, this phenomenon may be explained as an evolutionary occurrence as the heart and MB are congenital diseases. However, there was no left dominant heart in patients with MB of the RCA; but, its pathophysiology remains unknown.

Limitation

There exist few limitations in our study. MB involving the LCX artery is a rare disease, and the number of patients in the study group was small. Some biases may exist because all cases in this study underwent CCTA for chest discomfort, and were otherwise asymptomatic. There are no follow up data in this study.

Conclusions

MB of the LCX artery were mostly located in the mid-segment of LCX artery and mostly present superficially and was long bridging. The CT-FFR were normally present in isolated MB of the LCX artery. If a patient presents with chest discomfort, chest pain, and other cardiac symptoms, CCTA should be performed to check the condition of the coronary artery irrespective of a history of hypertension. Bridging of the LCX artery is longer than that of the other coronary arteries. CT-FFR has a false result in the measurement on MB in patients with chest pain or chest discomfort.

Declarations

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Figures

Figure 1

Flow chart of inclusion and exclusion. MB, myocardial bridging; CCTA, coronary computed tomography angiography; LCX, left circumflex artery; OM, obtuse marginal branch; LAD: left anterior descending coronary artery; RCA: right coronary artery

Figure 2

A 42 years old woman with chest pain for a long time but ECG was present normal. Right coronary dominance. Patient with deep MB at the middle segment of LAD (white arrow) and without atherosclerosis and other cardiovascular diseases. a: VR of coronary artery tree; b: An oblique image of the LAD.

Figure 3

Image of MB involving the RCA. a row: A 58 years old male with dizzy but ECG normal, right coronary dominance, with MB in the proximal segment of RCA (white arrow); brow: A 59 years old female with chest pain but ECG normal, right coronary dominance, patients with MB in the middle segment of RCA (white arrow); c row: A 67 years old male with chest discomfort and T wave abnormal, right coronary dominance, with MB in middle distal of RCA (white arrow).The first column is the volume rendering imaging of the coronary artery tree; the second column is the oblique image of the right coronary artery.

Figure 4

MB of LCX. a: a 50 years old male with hypertension and chest discomfort but the ECG presents normal. CTA image showed a superficial MB of the middle segment of LCX (white arrow) and the right dominant heart. b: a 52 years old female with hypertension and chest discomfort but the ECG presents normal. CTA image showed a deep MB of the distal segment of LCX (white arrow) and right dominant heart. The first column is the volume rendering imaging of the coronary artery tree; the second column is the oblique image of the right coronary artery.

Figure 5

A 70 years old female with hypertension and underwent CCTA because of chest discomfort. And the examination result illustrates this patient with MB in the middle segment of the OM branch (white arrow). And the LCX of these patients is absent. a is the volume rendering image of the heart; b is the second is the oblique image of OM.

Figure 6

The volume rendering imaging of coronary artery tree of three dominant coronary heart