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The Functional Effects of Intramural Course of Coronary Arteries and its Relation to Coronary Atherosclerosis

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ABSTRACT

OBJECTIVES This study observed hemodynamic consequences of myocardial bridging and its relation to coronary atherosclerosis.

BACKGROUND Myocardial bridging is seen as intramural course by computed tomography angiography (CTA) or systolic compression by invasive coronary angiography. Segments with myocardial bridging are in previous studies closely associated with proximal atherosclerotic plaques.

METHODS We prospectively studied 100 patients 63 ± 7 years of age with intermediate likelihood of coronary artery disease. Segments with superficial (>1 mm) or deep (>2 mm) intramural course were identified using CTA. Myocardial perfusion was studied by 15-Oxygen water positron emission tomography and systolic compression by invasive coronary angiography.

RESULTS Myocardial bridging was detected in 34 (34%) patients in 48 different vascular segments. Of these, 24 (50%) were deep and systolic compression was present in 14 (29%). In patients without obstructive coronary artery disease, myocardial stress perfusion distal to myocardial bridging was comparable with remote control regions (3.3 ± 0.9 ml/g/min vs. 3.3 ± 0.7 ml/g/min, n = 24, p = 0.88). Stress perfusion was comparable in segments with and without systolic compression (3.0 ± 0.9 vs. 2.7 ± 1.0 ml/g/min, p = 0.43). Atherosclerotic plaques were more frequent in proximal (71%) than myocardial bridging (7%) or distal (21%) segments. The presence of atherosclerosis and the average number of plaques were comparable in coronary arteries with and without myocardial bridging (73% vs. 60%, p = 0.14 and 2.0 ± 1.7 vs. 1.5 ± 1.6, p = 0.06). Median Agatston coronary calcium score was not elevated in vessels with myocardial bridge (15 [interquartile range: 0, 129] vs. 50 [interquartile range: 0, 241], p = 0.21).

CONCLUSIONS Myocardial bridging of coronary arteries is common on CTA, but only approximately one-third of these show systolic compression. Myocardial bridging is not associated with reduced myocardial perfusion during vasodilator stress. Atherosclerosis is located predominantly proximal to myocardial bridging but atherosclerotic burden and presence of vulnerable plaques were comparable. (J Am Coll Cardiol Img 2015;8:697–704) © 2015 by the American College of Cardiology Foundation.

Myocardial bridging (MB) was originally defined in autopsies as an anatomic variation in which myocardium overlies a segment of coronary artery. Later, with a widespread use of invasive coronary angiography (ICA), MB was seen as a systolic compression of a coronary artery segment (1,2). Currently, computed tomography angiography (CTA) has enabled noninvasive imaging of

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ABBREVIATIONS AND ACRONYMS

CAD = coronary artery disease

CTA = computed tomography angiography

FFR = fractional flow reserve

ICA = invasive coronary angiography

LAD = left anterior descending

LCX = left circumflex

MB = myocardial bridging

MBF = myocardial blood flow

PET = positron emission tomography

RCA = right coronary artery

SPECT = single-photon emission computed tomography

coronary vasculature. MBs can be identified by CTA as an intramural course of coronary artery and anatomic definition of MB has re-emerged (1–4).

MB has been considered a relatively common and benign congenital variation of coronary anatomy. However, some studies and case reports have associated it with angina pectoris, depressed left ventricular function, arrhythmia and sudden death (1,2). Myocardial blood flow (MBF) occurs predominantly during diastole while coronary compression of the myocardial bridge is at systole. However, intracoronary Doppler studies have shown effects beyond systolic compression (5–8). In some of the previous clinical single-photon emission computed tomography (SPECT) studies, severe systolic compression has been associated with reversible ischemia (9–12).

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Hybrid imaging using positron emission tomography (PET) and computed tomography (CT) allows simultaneous imaging of coronary anatomy and MBF in quantitative terms by PET. To our knowledge, there are no clinical studies evaluating the effects of intramural course of coronary artery in CTA on absolute MBF. In this study, we evaluated the effects of MB defined by either anatomical (intramural course) or functional (systolic compression) criteria on absolute MBF in response to pharmacologic stress as assessed with 15-Oxygen (^{15}O) water myocardial perfusion PET. We also evaluated the relationship between MB and coronary atherosclerosis in these patients.

METHODS

STUDY POPULATION AND DESIGN. The study group consisted of 100 outpatients 63 ± 7 years of age. Patients were evaluated for stable chest pain with a 30% to 70% pre-test likelihood of coronary artery disease (CAD). Exclusion criteria were previous myocardial infarction, unstable angina pectoris, atrial fibrillation, second- or third-degree atrioventricular block, heart failure (New York Heart Association functional class IV), iodine allergy, pregnancy, severe kidney failure, and symptomatic asthma. Patients with previous CAD proven by ICA were excluded. Follow-up data on cardiac events was obtained from national health statistics. The study was performed according to the Declaration of Helsinki and it was approved by the local ethics committee. All individuals gave their informed written consent.

COMPUTED TOMOGRAPHY. Patients were scanned with a 64-row PET/CT scanner (GE Discovery VCT, General Electric Medical Systems, Waukesha, Wisconsin). The collimation was 64 × 0.625 mm, gantry rotation time was 350 ms, tube current was 600 to 750 mA, and voltage was 100 to 120 kV, depending on patient size. Patients received 800 ug sublingual nitrate before the scan. Intravenous metoprolol 0 to 30 mg was administered before the scan to reach a target heart rate of 60 bpm. Iodinated contrast infusion (60 to 80 ml of 400 mg iodine/ml iomeprol at 4 to 4.5 ml/s) was followed by a saline flush.

POSITRON EMISSION TOMOGRAPHY. PET studies were performed after an overnight fast. Alcohol and caffeine were prohibited 12 h before the study. Rest-stress perfusion cardiac PET was performed immediately after CT and ^{15}O-labeled water (900 to 1100 MBq) was injected (RadiowaterGenerator, Hidex Oy, Turku, Finland) at rest as an intravenous bolus over 15 s. A dynamic acquisition of the heart was performed (14 × 5 s, 3 × 10 s, 3 × 20 s, and 4 × 30 s), after which an adenosine-induced stress scan was performed. Adenosine infusion was started 2 min before the scan and continued at the rate of 140 μg/kg/min until the scan was completed. The values of MBF were expressed as ml/g/min. The details are described in our previous study (13).

INVASIVE CORONARY ANGIOGRAPHY. All patients underwent ICA performed with Siemens Axiom Artis coronary angiography system (Siemens, Erlangen, Germany). Quantitative analysis of coronary angiograms (Quantcore, Siemens) for CAD and assessment for systolic compression was performed by an experienced reader. A 17-segment standard model was used (14).

PET/CT IMAGE ANALYSIS AND INTERPRETATION. CTA images were analyzed according to the standard 17-vessel segment American Heart Association model (14). To evaluate the presence of intramural course, multiplanar reconstruction images were used. The intramural course was defined as superficial (1 to 2 mm) or deep (>2 mm of overlying myocardium) according to the definitions used in the previous studies (4,15,16). PET images were analyzed with Carimas software (13). Standard polar plots and parametric volume of the heart were produced, allowing image fusion with ADW 4.4 software (CardiIQFusion, General Electric Medical Systems, Milwaukee, Wisconsin). PET/CT hybrid images were used to match coronary artery segments affected by MB to corresponding myocardial flow areas. Myocardial segments for flow analysis were chosen distal to MB and myocardial areas of other coronary branches affected

by obstructive CAD were avoided as possible. An example of PET/CT imaging of myocardial bridging is shown in Figure 1. Plaque morphology was evaluated as described in Motoyama et al. (17).

STATISTICAL ANALYSIS. The mean and the standard deviation were calculated for variables. The coronary calcium score is expressed as median and interquartile range (IQR). Normally distributed variables were compared using the non-paired Student *t* test and other variables with the non-parametric Mann-Whitney U test. Nominal data was analyzed with a chi-square test. In multiple measurements from a single patient, the paired Student *t* test and Wilcoxon signed rank test or McNemar's test for nonparametric variables were used. No adjustments were made for multiple observations within individuals for segment-wise analyses or for multiple comparisons against control regions. Two-tailed p values of 0.05 were considered statistically significant. Statistical analyses were performed using SPSS (SPSS, Inc., Chicago, Illinois).

RESULTS

GENERAL. The clinical characteristics of the patients are depicted in Table 1. The prevalence of MB was higher in men than in women (29 vs. 5, $p < 0.001$). MB was not related to conventional risk factors of CAD. The intramural course was detected in 34% of patients in 48 different vascular segments; 50% of these were defined as deep (>2 mm of overlying myocardium). The intramural courses were mostly located in the left anterior descending (LAD) and diagonal branches (n = 18), in the left circumflex (LCX) and marginal branches (15), or in the intermediate coronary artery (12), only a few were in the right coronary artery (RCA) (n = 3). Presence of typical angina pectoris and positive exercise–electrocardiogram were comparable in patients with and without intramural course (59% vs. 52%, p = 0.47 and 87% vs. 79%, p = 0.32) or patients with and without systolic compression (75% vs. 51%, p = 0.11 and 84% vs. 85%, p = 0.95). Frequency of angina pectoris and positive exercise test were still comparable in patients with and without intramural course after patients with CAD were excluded (61% vs. 42%, p = 0.17 and 68% vs. 80%, p = 0.30). This was also the case with systolic compression (44% vs. 83%, p = 0.06 and 78% vs. 71%, p = 0.72). Patients with deep MB had higher prevalence of angina pectoris but comparable frequency of positive exercise test compared to patients without MB (75% vs. 44%, p = 0.02 and 81% vs. 87%, p = 0.53), but after the patients with CAD were excluded both were comparable (67% vs. 42%, p = 0.13 and 69% vs. 80%, p = 0.39). After a median follow-up of 5 years, 3 patients had died (non-cardiac causes), 1 patient had unstable angina, 1 had myocardial infarction, and 1 had elective coronary artery bypass surgery. The events were equally distributed in patients with and without MB (3 vs. 2).

TABLE 1 Characteristics of All Patients and Patients With Any or Deep Myocardial Bridging*

	All Patients (N = 100)	MB (n = 34)	Deep MB (n = 22)
Men/women	58/42	29/5	19/3
Age, yrs	63 ± 7	63 ± 7	64 ± 8
Significant CAD, >70% or FFR <0.8	35 (35)	14 (41)	8 (36)
1 vessel	21	7	4
2 vessel	12	5	3
3 vessel	2	2	1
Symptom			
Typical AP	52 (52)	19 (56)	14 (63)
Atypical AP	35 (35)	12 (35)	6 (27)
Nonanginal	9 (9)	1 (3)	1 (5)
Medication			
Aspirin	72 (72)	26 (76)	17 (77)
Beta-blocker	51 (51)	18 (53)	11 (50)
Statin	60 (60)	21 (62)	12 (55)
ACE inhibitor / AT2 receptor-antagonist	32 (32)	14 (41)	8 (36)
Calcium-channel blocker	10 (10)	5 (15)	3 (14)
Nitrate	7 (7)	2 (6)	2 (9)

Values are n, mean ± SD, or n (%). *>2 mm of overlying myocardium.
ACE = angiotensin-converting enzyme; AP = angina pectoris; AT2 = angiotensin 2 receptor; CAD = coronary artery disease; FFR = fractional flow reserve.

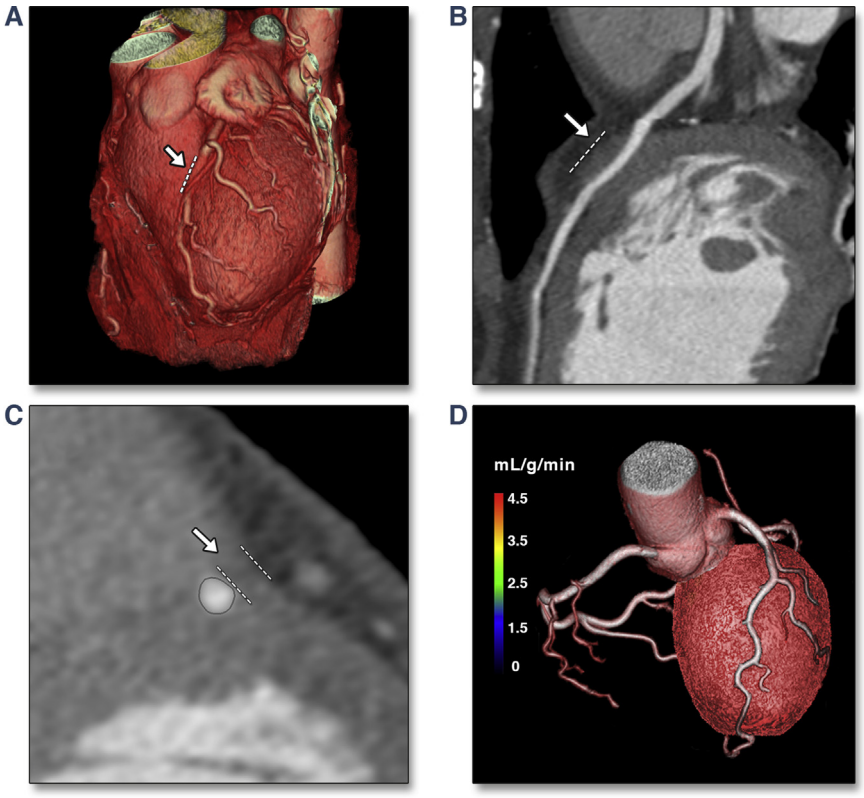
INTRAMURAL COURSE OF CORONARY ARTERIES AND MYOCARDIAL BLOOD FLOW. The effects of intramural coronary arteries on quantitative MBF are shown in Table 2. There was no difference in hyperemic flow in the myocardium distally to the segments with MB and the remote control segments of the same patients (2.8 ± 1.1 vs. 2.9 ± 1.0 ml/g/min, p = 0.55). Flow distal to a superficial and deep intramural course (3.0 ± 0.9 vs. 2.8 ± 1.2 ml/g/min, p = 0.47) were

TABLE 2 Myocardial Blood Flow Distal to Coronary Artery Segments With Myocardial Bridging Versus Remote Myocardial Control Region of the Same Patients

	Control Region	MB >1 mm	p Value (vs. Control)	MB >2 mm	p Value (vs. Control)
Patients, n		34		22	
Flow rest, ml/g/min	0.9 ± 0.2	1.1 ± 0.3	<0.001	1.0 ± 0.3	0.001
Flow hyperemic, ml/g/min	2.8 ± 1.1	2.9 ± 1.0	0.55	2.8 ± 1.1	0.89
Patients with significant CAD excluded (>70% stenosis or FFR <0.8)					
Patients, n		24		16	
Flow rest, ml/g/min	0.9 ± 0.2	1.1 ± 0.2	0.001	1.0 ± 0.2	0.01
Flow hyperemic, ml/g/min	3.3 ± 0.9	3.3 ± 0.7	0.88	3.3 ± 0.9	0.99

Values are mean ± SD.
Abbreviations as in Table 1.

FIGURE 1 PET/CT Hybrid Imaging of Myocardial Bridge



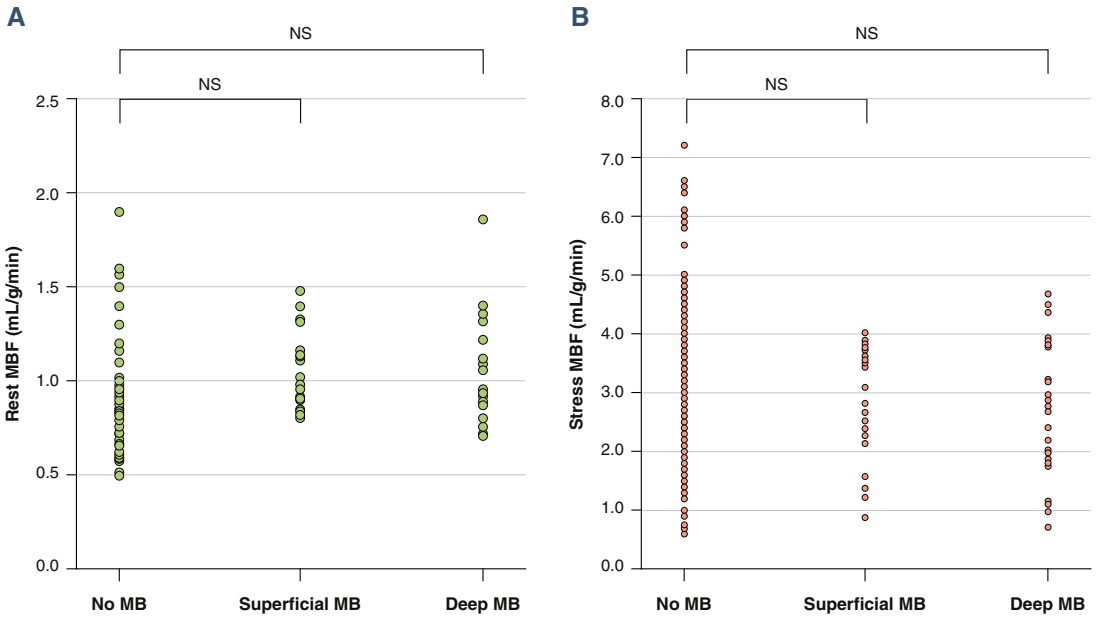
Positron emission tomography (PET)/computed tomography (CT) images of intramural course of the mid left anterior descending artery. CT coronary angiography images are shown. **(A)** Three-dimensional (3D) volume reconstructed image. **(B)** Multiplanar reconstructed image. **(C)** Cross-section at the site of myocardial bridge. Overlying myocardium is shown by **white arrow** and **white line**. **(D)** Fusion image of 3D coronary CT angiogram and quantitative myocardial perfusion map assessed by 15-Oxygen water PET during adenosine stress. Myocardial perfusion distal to the myocardial bridge is normal (4.4 ml/g/min) as indicated by **red** color.

comparable. There were no differences in regional blood flow at rest or during stress between myocardial segments affected by intramural course and matched coronary regions from control patients (Figure 2, Table 3). There was no statistically significant association between rest or hyperemic MBF and superficial or deep myocardial bridging in univariate analysis corrected for multiple comparisons (p always $>$ 0.05).

INTRAMURAL COURSE OF CORONARY ARTERIES AND SYSTOLIC COMPRESSION. On ICA, systolic compression was present in 14 of 48 (29%) segments with coronary artery intramural course on CTA. Of these 14 segments, 5 were located in the LAD or diagonal branches, 5 in the LCX or obtuse marginal branches, and 4 in an intermediate coronary artery. There was no difference in frequency of systolic compression in superficial and deep MB on CTA (6 vs. 8, p = 0.52). There were no significant differences in rest or hyperemic flows between MB with or without systolic compression on ICA (1.0 ± 0.2 ml/g/min vs. 1.0 ± 0.2 ml/g/min, p = 0.68 and 3.0 ± 0.9 ml/g/min vs. 2.7 ± 1.0 ml/g/min, p = 0.43, respectively). All systolic compressions on quantitative ICA were <50%. On univariate analysis, systolic compression was not associated with decreased rest flow or hyperemic flow (p always $>$ 0.05).

RELATION BETWEEN ATHEROSCLEROSIS AND INTRAMURAL COURSE OF THE CORONARY ARTERY. Atherosclerotic changes were observed in 186 of 300 (62%) coronary arteries in the 79 of 100 patients. The presence of atherosclerosis on CTA and the average number of plaques were comparable in coronary arteries with and without MB (73% vs. 60%, p = 0.14 and 2.0 ± 1.7 vs. 1.5 ± 1.6, p = 0.06). Plaques were more frequently located proximally to the segments with MB (n = 20, 71%) than at the segment with MB (n = 2, 7%) or

FIGURE 2 Myocardial Blood Flow in Myocardium Distal to Myocardial Bridge



Absolute average myocardial blood flow at rest **(A)** and adenosine stress **(B)** in myocardium distal to myocardial bridges with superficial (1 to 2 mm) (n = 19) and deep (≥2 mm) (n = 22) intramural course compared to myocardial coronary artery areas of the patients without myocardial bridging. Patients with coronary artery disease are not excluded. Myocardial blood flow is measured as ml/g/min. N = nonsignificant.

distally to the segment with MB (n = 6, 21%). The median Agatston coronary calcium score and number of calcified plaques were not elevated in vessels with MB (15 [IQR: 0, 129] vs. 50 [IQR: 0, 241], p = 0.21 and 0.6 ± 1.0 vs. 0.6 ± 1.0, p = 0.46). The number of mixed and soft plaques was also comparable (1.1 ± 1.3 vs. 0.7 ± 1.1, p = 0.06 and 0.3 ± 0.6 vs. 0.2 ± 0.5, p = 0.38). Superficial or deep MB had no difference in the average number of plaques, median coronary calcium score, or frequency of obstructive CAD (2.2 ± 1.9 vs. 1.9 ± 1.6, p = 0.64; 20 [IQR: 0, 146] vs. 152 [IQR: 0, 481], p = 0.07 and 29% vs. 30%, p = 0.94). Plaque morphology in plaques located proximal to MB and in vessels with no bridging was comparable (Table 4).

Systolic compression in ICA was not related to the coronary calcium score (76 [IQR: 0, 228] vs. 16 [IQR: 0, 135], p = 0.38) or the number of atherosclerotic plaques when compared to other coronary arteries (2.2 ± 1.7 vs. 1.5 ± 1.6, p = 0.18). Moreover, the systolic compression was not related to the number of calcified, mixed, or non-calcified plaques in CTA (0.9 ± 1.1 vs. 0.6 ± 0.9, p = 0.17; 1.2 ± 1.2 vs. 0.8 ± 1.1, p = 0.18; and 0.2 ± 0.4 vs. 0.2 ± 0.5, p = 0.64). We further analyzed the subgroup of patients with intramural coronary artery course (n = 12) and abnormally reduced MBF (<2.4 ml/g/min). Reduced MBF was explained by an obstructive CAD in 10 of 12 patients. In the remaining 2 patients, the etiology of reduced MBF remained unexplained.

DISCUSSION

Several previous studies have indicated that MB can be associated with myocardial ischemia, potentially related to the mechanical compression of the

TABLE 3 Myocardial Blood Flow at Rest and Adenosine Stress in the Regions With Myocardial Bridging and Matched Control Regions in Patients Without Bridging*

	No MB	MB >1 mm	p Value (vs. no MB)	MB >2 mm	p Value (vs. no MB)
LAD	84	16		7	
Rest flow, ml/g/min	1.0 ± 0.3	1.0 ± 0.2	0.79	0.9 ± 0.1	0.29
Flow hyperemic, ml/g/min	3.0 ± 1.2	3.1 ± 0.8	0.8	3.0 ± 1.0	0.97
LCX	77	22		12	
Rest flow, ml/g/min	1.1 ± 0.3	1.0 ± 0.2	0.050	0.9 ± 0.2	0.03
Flow hyperemic, ml/g/min	3.4 ± 1.2	2.8 ± 1.2	0.050	2.7 ± 1.5	0.09
RCA	95	3		3	
Rest flow, ml/g/min	0.9 ± 0.3	1.4 ± 0.5	0.004	1.4 ± 0.5	0.004
Flow hyperemic, ml/g/min	3.2 ± 1.2	2.5 ± 0.6	0.30	2.5 ± 0.6	0.30

Values are n or mean ± SD. *LAD, LCX, and RCA include their corresponding side branches. Patients with CAD are not excluded.

LAD = left anterior descending; LCX = left circumflex; MB = myocardial bridge; n = number; RCA = right coronary artery; other abbreviations as in Table 1.

TABLE 4 Atherosclerotic Plaque Morphology on Computed Tomographic Angiography Proximal to Intramural Course

	No Intramural Course (n = 259)	Intramural Course (n = 17)	p Value
Soft plaque	66 (26)	6 (33)	0.47
Soft or mixed plaque	122 (47)	13 (65)	0.13
Remodeling, >10%	53 (21)	5 (10)	0.10
Remodeling, >15%	41 (16)	4 (8)	0.18
Spotty calcification	35 (14)	4 (8)	0.32

Values are n (%).

coronary artery or atherosclerosis in the coronary segment. This is of clinical importance because it could cause the clinical symptom of chest pain.

Intramural coronary arteries were a common finding on CTA in our study. Only approximately one-third of these show systolic compression on ICA and none severe compression (>50%). To our knowledge, this is the first study to evaluate the hemodynamic significance of intramural course and systolic compression. Absolute MBF during vasodilator stress was not influenced by myocardial bridges. Coronary atherosclerosis was predominantly localized proximal to the coronary segment with MB, which is known from previous studies (1,2,5,18). However, the atherosclerotic burden in coronary arteries and patients was not increased. Plaque morphology proximal to MB was comparable to other vessels. Therefore, according to our findings, MB is not associated with more advanced atherosclerotic disease.

In a study from Gawor et al. (9), 42 patients with systolic compression without CAD in the LAD in ICA underwent gated technetium 99 (Tc-99m) SPECT with an exercise stress. They found a correlation between summed stress score and a degree of systolic narrowing. All perfusion abnormalities (12 of 42 patients) were found in the segments with >50% systolic compression (9). Lee et al. (10) also assessed patients with systolic compression in the mid LAD and found that 10 of 14 patients had a perfusion defect in Thallium-201 SPECT with dipyridamole stress. Defects were seen in patients with greater than 75% systolic narrowing. Vallejo et al. (11) evaluated the differences in Tc-99m SPECT results using exercise or pharmacological stress in 16 patients with systolic compression seen in the mid LAD by ICA. Results with both stressors were comparable. An older study from Ahmad et al. (12) with Thallium-201 exercise SPECT showed perfusion defect in 3 of 7 patients with greater than 75% systolic compression. A study focused on diastolic fractional flow reserve (FFR) showed that FFR was decreased in the segments with systolic compression (19). On the other hand, some studies have failed to show any association between systolic compression and MBF. In a study from Soran et al. (20), only 1 of 26 patients demonstrated reversible ischemia in Tc-99m exercise SPECT despite systolic compression. In other studies, Greenspan et al. (21) (n = 7) and Voss et al. (22) (n = 21) did not find any perfusion abnormalities using 201-thallium exercise SPECT in patients with systolic compression in the LAD.

Our findings of unaffected MBF in the presence of intramural course or systolic compression of the coronary artery are in contrast to the majority of previous studies. One explanation for this is that we included nonselected patients undergoing CTA due to suspected CAD. Previous studies have focused on patients with detected systolic compression. Based on our less selected patient population, the prevalence of severe systolic compression appears to be a rare phenomenon. Unlike most of the other studies, our study was not limited to the mid LAD. A considerable amount of MB was found in other coronary artery branches. The prevalence of systolic compression in intramural segments was 29%, which is similar to previous studies (21% to 46%) (16,23,24). Our results of unaffected MBF are in line with a previous observation that intramural courses are associated with good prognosis (25).

STUDY LIMITATIONS. A threshold of 50% to 75% of systolic compression seems to be required to induce myocardial perfusion defects (9–12). In the present patient population, all systolic compressions were less than 50%. However, as shown by Escaned et al. (19), systolic compression is a dynamic stenosis and is not always seen in a resting ICA. Furthermore, systolic compression of MB might be additive to coronary plaque. We cannot exclude that the use of beta-blockers affected MBF by lengthening the diastole and alleviating systolic compression. However, we have previously shown that beta-blockers received during CTA had no effect on quantitative MBF in our PET/CT protocol (26). Adenosine as a stressor differs from exercise stress but is comparable to dipyridamole used in previous studies. Increased heart rate in exercise and dobutamine stress changes the relative length of systole to diastole and might be more effective than pharmacologic vasodilation in uncovering possible perfusion abnormalities caused by MB. Lin et al. (19) and Escaned et al. (27) described dobutamine in their articles as an effective stressor in uncovering physiologic effects of MB. However, Vallejo et al. (11) found comparable results using dipyridamole and exercise SPECT perfusion imaging. Because adenosine also dilates microvasculature, vasodilator stress may theoretically increase coronary susceptibility to the

systolic compression of myocardial bridges. MB was frequently associated with proximal atherosclerotic plaque, which is a confounding factor when evaluating the effect of MB to MBF. Our study was not designed and is underpowered to study the effects of MB on prognosis. We also acknowledge the possibility of type 2 statistical error that could occur due to small number of patients with MB without obstructive CAD.

CONCLUSIONS

The intramural course of coronary arteries is common on CTA, but only 29% of these have systolic compression. MB is not associated with abnormal myocardial perfusion during vasodilator stress. Atherosclerotic lesions were located predominantly proximal to the intramural coronary arteries. Bridging is not linked with accelerated atherosclerosis or vulnerable plaques.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Myocardial bridge seen as an intramural course by computed tomography angiography or systolic compression <50% by invasive coronary angiography is not associated with reduced myocardial perfusion during vasodilator stress. Most coronary artery plaques are located proximal to myocardial bridge. However, myocardial bridging is not associated with increased atherosclerotic burden or vulnerable plaques. Severe systolic compression is a rare phenomenon.

TRANSLATIONAL OUTLOOK: The intramural course of the coronary artery is a frequent finding in a computed tomography angiography study. Usually they cause only mild dynamic stenosis of the coronary artery during systole and are associated with a favorable prognosis. However, additional clinical studies are needed to show frequency of severe (>50%) systolic compression and its effect on myocardial blood flow and cardiovascular prognosis.

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