The morphologic and functional features of LAD myocardial bridging at multi detector computed tomography coronary angiography: correlation with coronary artery disease

Çok kesitli bilgisayarlı tomografi ile saptanan sol ön inen arter miyokart köprülerinin morfolojik ve fonksiyonel özellikleri ile koroner arter hastalığı ilişkisinin değerlendirilmesi

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ABSTRACT

Objectives: The aim of this study was to retrospectively evaluate the morphologic and functional features of myocardial bridging (MB) and to investigate the impact of morphologic features on presence of atherosclerosis with multi-detector computed tomography (MDCT) coronary angiography.

Study design: The study population consisted of 191 consecutive patients. Besides coronary lesions, morphologic features of the MB (depth, length and the distance of the tunneled artery from the left coronary ostium) were analyzed.

Results: MDCT detected MB on left anterior descending artery in 41 patients (21.5%). The prevalence of atherosclerotic plaques proximal to the MB of LAD was 49% (20/41). There was a statistically significant correlation between percentage of systolic compression and depth of the tunneled segment ($r=0.538$, $p<0.01$). There was no relation between distance of the tunneled segment from the ostium and degree of systolic compression. No significant correlation was found between percentage of systolic compression and length of the tunneled segment ($r=0.058$, $p=0.721$). Morphologic features of MB were not related to the presence of CAD in proximal segments.

Conclusion: MDCT coronary angiography depicts the morphologic and functional features of the MB in detail. The depth of MB segment was correlated with systolic compression of MB. There was no relationship between distance of the tunneled segment from the ostium and systolic compression.

ÖZET

Amaç: Çalışmamızın amacı çok kesitli bilgisayarlı tomografi (ÇKBT) ile saptanan sol ön inen arter (LAD) miyokart köprülerinin (MK) morfolojik ve fonksiyonel özelliklerini ve koroner arter hastalığı ile ilişkisini geriye dönük olarak değerlendirmektir.

Çalışma planı: Çalışmaya ÇKBT ile koroner anjiyografi yapılan 191 ardışık hasta dahil edildi. Koroner lezyonlar ve MK'nin morfolojik özellikleri (derinlik, uzunluk, koroner ağzına olan uzaklığı) incelendi.

Bulgular: Çok kesitli bilgisayarlı tomografi ile LAD'de 41 hastada (%21.5) MK tespit edildi. MK proksimalinde aterosklerotik lezyon %49 (20/41) oranında saptandı. MK segmentinin derinliği ile sistolik baskının derecesi arasında istatistiki olarak anlamlı ilişki saptandı ($r=0.538$, $p<0.01$). MB segmentinin koroner ağzından uzaklığı ile sistolik baskının derecesi arasında ilişki saptanmadı. MK segmentinin uzunluğu ile sistolik baskı derecesi arasında ilişki saptanmadı ($r=0.058$, $p=0.721$). MK'nin morfolojik özellikleri ile proksimal bölümde saptanan koroner arter hastalığı arasında ilişki bulunamadı.

Sonuç: Çok kesitli bilgisayarlı tomografi ile MK'nin fonksiyonel ve morfolojik özellikleri iyi bir şekilde belirlenebilir. MK olan koroner segmentinin derinliği, baskı derecesi ile ilişkili olup MK özellikleri ile MK'nin proksimal bölümünde gözlenen koroner arter hastalığı arasında ilişki saptanmamıştır.

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Abbreviations:

CAD	*Coronary artery disease*
LAD	*Left anterior descending artery*
MB	*Myocardial bridging*
MDCT	*Multi-detector computed tomography*

Myocardial bridging (MB) is recognized as an inborn abnormality of the coronary artery in which an epicardial artery lies in the myocardium for part of its course. Although MB is usually considered a benign condition, myocardial ischemia, ventricular septal rupture, arrhythmias, exercise-induced atrioventricular conduction block, early death after cardiac transplantation, and sudden death have been reported in association with MB.[1-5]

The estimated frequency reported varies from 0.5 to 2.5% when assessed by conventional coronary angiography (CCA), but detection rate within some autopsy series is 15-85%.[6,7] Multiple factors have been held responsible for this discrepancy, including the length and depth of tunneled artery, with only deeply-located coronary artery segments appearing to be sufficiently compressed during systole to be recognized on CCA.[8,9] Advances in detector technology in the past decade have greatly improved the feasibility of coronary artery imaging with multi-detector computed tomography (MDCT).

It is widely accepted that the segment proximal to the bridge frequently shows atherosclerotic plaque formation.[10,11] Previous MDCT and autopsy studies report that the morphologic features (depth and length of tunneled segment) of the MB at the left anterior descending artery (LAD) influence evolution of atherosclerosis.[12,13] However, there are few MDCT studies regarding the morphologic features of MB and coronary artery disease (CAD). By using MDCT, we sought to retrospectively evaluate the morphologic and functional features of LAD MB, including its correlation with CAD.

PATIENTS AND METHODS

Patient population

The study population consisted of 191 consecutive patients (50 women; mean age, 53.82±11.97 years; range 20-84 years) who underwent coronary artery angiography with MDCT. The patients were referred for MDCT angiography due to clinically suspected coronary artery disease. Exclusion criteria for MDCT were known allergy to iodine-contrast medium, pregnancy, renal dysfunction (serum creatinine >1.2 mmol/l), and arrhythmias such as atrial fibrillation. The study was approved by the local ethics committee.

MDCT examination technique

Data were acquired using a 64-detector row spiral CT scanner (Aquilion 64 Slice, Toshiba Medical Systems, Tokyo, Japan). The scan parameters were 64x0.5 mm detector collimation, pitch 0.2-0.45 (depending on heart rate), rotation time 400 ms, tube voltage 120 kV and current 600-900 effective mAs. ECG-dependent tube current modulation was applied in regular heart rates. Scan direction was cranio-caudal during a single mid-inspiratory breath-hold. The scanning range covered the entire heart from the level of the tracheal bifurcation to the diaphragm. A bolus of 80 ml iodine contrast agent iobitridol (Xenetix 350, 350 mg/ml; Guerbet, France) was injected intravenously into an antecubital vein at a flow rate of 5-6 ml/s using a dual-head power injector, followed by 50 mL saline chaser (5 ml/s). The scan was started automatically by applying "sure start" technique (ascending aorta, threshold 160 HU). A beta-blocker was given intravenously before the MDCT scan if the heart rate was greater than 70 beats per minute (5-15 mg metoprolol intravenously).

Image reconstruction and data analysis

Retrospective reconstructions were performed in all cardiac phases with 10% steps of the R-R interval. Images were reconstructed with a section thickness of 0.5 mm, a reconstruction increment of 0.3 mm, image matrix 512x512, and a FOV of 180-240 mm. Data were transmitted to Vitrea 2 workstation (Vital Images Inc., Plymouth, Minnesota), and images were reconstructed with multiple post-processing methods. The MDCT images were evaluated in consensus by two radiologists (R.C., N.T.), experienced in cardiovascular radiology. One diastolic and one systolic data set were selected with the best image quality. Image quality was graded on a 3-point scale as: grade 1, good image quality (no artifacts); grade 2, acceptable image quality (with minor limitations, e.g. mild artifacts); or grade 3, insufficient image quality (severe artifacts). LAD segments with a luminal diameter of less than 1.5 mm were excluded from analysis.

Myocardial bridge is defined as an epicardial segment of a coronary artery coursing through the myocardium. Transverse source images, multiplanar reformations (MPR), curved multiplanar reformations,

Table 1. **Demographic and clinical data of subjects with myocardial bridge**

	n	%	Mean±SD
No. of patients	41		
Age (years)			50.27±12.73
Male-to-female ratio	28/13		
Body mass index (kg/m²)			28.5±3.6
Family history	17	41	
Hypertension	17	41	
Hyperlipidemia	15	37	
Diabetes mellitus	8	20	
Smoking (current)	12	29	
No. of patients using β-receptor antagonist	11	27	
No. of patients using calcium channel blockers	3	7	

Values are number with percentage in parentheses.

and maximum intensity projections images were used for evaluating the intramyocardial course. Multiplanar and curved planar reformations were performed to demonstrate the relationship between coronary artery and adjacent muscle. Myocardial bridging was classified as either "deep" or "superficial". "Deep" myocardial bridging was defined as LAD being surrounded entirely by myocardium (depth ≥2 mm), whereas "superficial" bridges were defined as the surface not fully covered by myocardial fibers (depth <2 mm), but rather by a thin connective tissue.[9,14]

Location of the MB and distance of the MB segment from the left coronary ostium were recorded. The length and depth of the tunneled segment were measured with a digital caliper on curved MPR. The diameter of each tunneled segment was obtained in the curved MPR at the end-diastolic phase and at the end of the systole, with the smallest degree of motion artifacts. The percentage of systolic compression was calculated from the mean of the measurements in two different phases.

CAD was defined as atheromatous changes (calcified and non-calcified plaque) in the coronary artery wall. The MDCT coronary angiography findings for CAD were classified as follows: normal, no atheromatous change or luminal narrowing; mild disease, atheromatous changes without luminal narrowing; moderate disease, atheromatous changes with insignificant stenosis; and severe disease, atheromatous changes with significant stenosis. Segments proximal to the MB were defined as those within 2 cm of the proximal entry site of the MB.

Statistical analysis

PASS 2008 statistical software (NCSS, Kaysville, UT, USA) program was used in statistical analysis of the study's data. The Mann Whitney U test was employed for comparison of quantitative data (mean, SD, median, frequency). Chi-square test and Fisher's exact test were utilized for comparison of qualitative data. Spearman's correlation analysis was used for evaluation of associations between parameters. Results were evaluated at 95% confidence interval, at the significance level $p<0.05$.

RESULTS

All MDCT coronary angiography examinations were successfully completed in 191 patients, without any complications or discomfort due to contrast material. MB segments were detected on the LADs in 41 patients (21.5%, 13 women, mean age 50.27±12.73 years, range 20-78 years). The demographic and clinical data of patients with MB are summarized in Table 1. The tunneled segments were located in the proximal part of the LAD (n=8), in the middle part of the LAD (n=20) and in the distal part of the LAD (n=13). There was "deep" and "superficial" MB in 16 (39.1%) and 25 (60.9%) cases respectively (Table 2).

Mean distance of the tunneled artery from the left coronary ostium was 45.1±13.7 mm (range, 24-90

Table 2. Location and type of myocardial bridge in LAD coronary arteries

	n	%
Myocardial bridge location		
Proximal	8	19.5
Middle	20	48.8
Distal	13	31.7
Type		
Deep	16	39
Superficial	25	61

mm). Mean length of the tunneled artery was 28.9±11.9 mm (range, 10-65 mm). Mean depth of the tunneled segment artery in diastolic phase was 1.8±1.2 mm (range, 0.7-5.8 mm). Mean systolic compression of the tunneled segment was 10.1%±5.4. Mean systolic compression of the tunneled segment was 13.9%±5.7 in deep MB (range 8-26), and 7.72±3.49 in superficial MB-cases (range 3-18).

There was a statistically significant correlation between percentage of systolic compression and depth of tunneled segment (r=0.538, p<0.01) (Figure 1). There was a statistically significant difference regarding percentage of systolic compression between deep type MB and superficial type MB (p=0,001; p<0.01). No significant correlation was found between percentage of systolic compression and mean distance of the tunneled artery from the left coronary ostium (r=-0.134, p=0.403). Similarly, no significant correlation was found between percentage of systolic compression and length of the tunneled segment (r=0.058, p=0.721). Systolic compression percentages showed no statistically significant difference regarding localization of the MB (p=0.490; p>0.05).

Prevalence of atherosclerotic plaques proximal to the MB of LAD was 49% (20/41) (Figure 2a). Mild and moderate CAD was detected in 11 and 9 cases respectively. Mixed atheroma plaques were observed in 17 of 20 cases. Non-calcified plaques were observed in only 3 cases. There was no atherosclerotic plaque and stenosis in the intramyocardial segment of the LAD (Figure 2b). There was no statistically significant relationship between the morphologic features of the MB (depth, length and distance of the tunneled artery from the left coronary ostium) and the presence of CAD in segments proximal to MB (p>0.05).

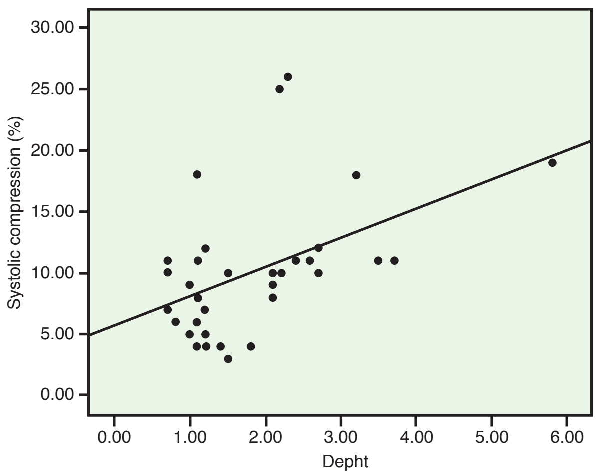

Figure 1. Correlation between the percentage of systolic compression and the depth of the tunneled segment (Pearson correlation, r=0.538, p<0.01).

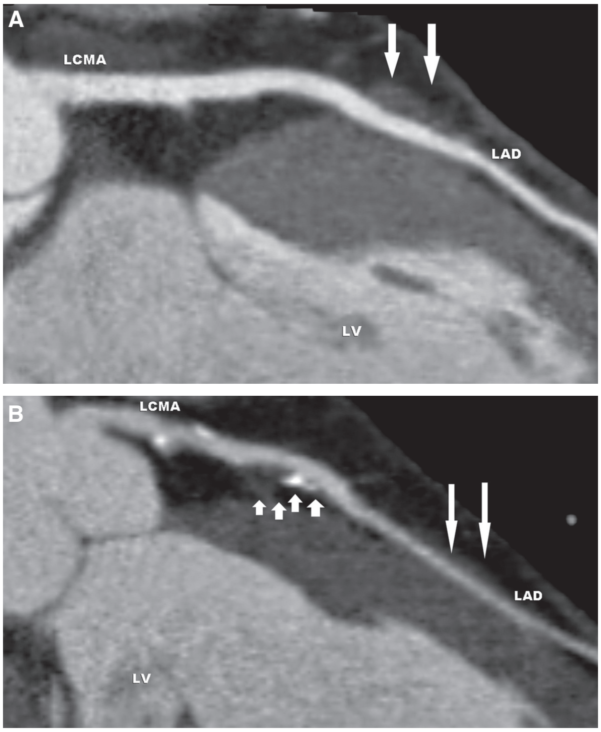

Figure 2. **(A)** Curved multiplanar reformat image shows tunneled segment completely surrounded by muscle fibers (long arrows) of the middle left anterior descending artery (LAD). No atherosclerotic changes are seen just proximal to and under myocardial bridging. **(B)** Curved multiplanar reformat image shows long segment of myocardial bridging (long arrows) on left anterior descending artery (LAD). Calcified and soft plaques (short arrows) are seen just proximal to myocardial bridging. Note that tunneled LAD segment is spared. LV: Left ventricle; LCMA: Left main coronary artery.

DISCUSSION

In the current study, we aimed to determine the morphologic and functional features of MB, and its relation to proximally-located atherosclerosis with MDCT imaging. While the systolic compression of MB was associated with depth, there was no relationship between distance of the tunneled segment from the ostium and the systolic compression, which was not reported previously in MDCT literature.

The lowest and the highest prevalence for MB detected by MDCT is 3.5% (16-detector MDCT) and 44% and we found the rate as 21.5%.[15] The mid portion of LAD was the site most frequently involved (20/41), in line with the literature.[10,11,16,17]

In our study, average distance from the left coronary ostium to MB segment was 4.5 cm, which is concordant with measurements obtained in previous anatomical studies.[11,12] Nevertheless, this distance – according to our findings – had no effect on the degree of systolic compression. This emphasizes that the main determinant of systolic compression could be depth of the tunneled segment. Consistently, systolic compression percentage in our cases with deep type MB was significantly higher than those with superficial type.

It is widely accepted that the arterial intima beneath MB is significantly spared from atherosclerotic changes.[11] This has been evident also in histopathology and image analysis studies.[17,18] Risse and Weiler have reported that the intima of the tunneled artery is significantly thinner than that of the proximal segment of the artery.[19] Furthermore, changes in endothelial cell morphology indicate that the intima beneath the myocardial bridge could be protected by hemodynamic factors such as high shear stress.[18] Consistently, we found no atherosclerotic plaque or stenosis inside any intramyocardial segment.

Prevalence of atherosclerotic plaque proximal to the MB of LAD was 49% (20/41) in our study.

There was not enough data to support that MB or degree of systolic compression of MB is an independent factor of atherosclerosis formation proximal to MB. The autopsy study of Ishikawa et al. suggested that anatomic properties of MB enhance development of atherosclerosis in the LAD proximal to MB.[20] In this autopsy study, patients with myocardial infarction had increased muscle thickness and muscle bridge index (multiplication of MB thickness by MB length) compared with patients without myocardial infarction with MBs.

However, Poullis et al. disagreed, and claimed that MB is likely to be protective factor, rather than a risk factor, as described by Ishikawa et al.[21] The 64-slice computed tomography coronary angiography study of Bayrak et al. suggested that there might be no relationship between MB and proximal atherosclerosis.[22]

Endothelial injury of the artery proximal to MB can be caused by localized arterial hypertension and turbulent or even retrograde blood flow up toward the coronary ostium at cardiac systole.[23,24] The intima of the segment proximal to MB is subject to decreased shear stress, which may contribute to the increased amount of vasoactive substances, such as endothelial nitric oxide synthase, endothelin-1, and angiotensin-converting enzyme, and this may facilitate formation of atherosclerotic plaques.[23-25] Pathological studies have revealed that the shape of endothelial cells is flat and polygonal with a defective surface. These defective cells are likely to be exfoliated in the segment proximal to MB and the segment is susceptible to atherosclerosis.[23,24] Depth of MB is related to compression degree of MCA and longer bridges are associated with more severe systolic compression.[23,24,26,27] So, one may think that higher systolic compression of MB might induce more endothelial injury and severe atherosclerosis in the segment proximal to MB. In the present study, no significant correlation was found between percentage of systolic compression and length of the tunneled segment. Also, there was no statistically significant relationship between the morphologic features of the MB (depth, length and distance of the tunneled artery from the left coronary ostium) and the presence of CAD in segments proximal to MB.

The main limitation of our study was lack of an additional control group including healthy volunteers free of any coronary artery disease. Moreover, the study was limited to MDCT findings, and did not include any clinical data. Also, intravenous administration of beta-blockers for heart rate control may decrease the rate of systolic compression of MB segments.

In conclusion, MDCT coronary angiography depicts the morphologic (lumen, wall, depth, length) and functional (systolic compression) features of the MB in detail, unlike other imaging modalities. Systolic compression may be of particular importance in "deep MB". The relation between morphologic features of MB and proximal atherosclerosis should be researched in further studies including larger study groups.

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Key words: Coronary artery disease; coronary disease/complications; myocardial bridging; tomography, X-ray computed.

Anahtar sözcükler: Koroner arter hastalığı; koroner hastalık/komplikasyonlar; miyokardiyal köprüleşme; bilgisayarlı tomografi.