The coronary arteries normally have an epicardial course. A myocardial bridge (MB) is a congenital condition in which a segment of coronary artery goes intramurally through the myocardium beneath a muscle bridge. The coronary artery segment covered by the MB is called a "tunneled" artery. The angiographic incidence of MB has been reported as between 0.5% and 2.5%, but is between 15% and 85% pathologically.\(^1,2\) The MB is most commonly seen with the left anterior descending coronary artery (LAD).\(^3\) Atherosclerotic change has known to be spared in tunneled segments, more frequent in the segment proximal to MB.\(^3\) Generally, it is a benign condition, but has been associated with angina, ischemia or infarction, arrhythmia, and sudden death.\(^1,4–8\) The symptoms are considered to be caused by coronary ischemia attributed to a reduction in blood flow subsequent to coronary compression by the MB during systole or by delayed arterial relaxation in diastole, or both.\(^9–11\)

The current diagnostic methods are coronary angiography (CAG), intravascular ultrasound and intracoronary Doppler, which are all invasive modalities. Recently, multidetector computed tomography (MDCT) was proposed as a method of reliably and noninvasively assessing coronary artery plaque, stenosis, and complex anatomy, and also visualizing the neighboring myocardium and the heart chambers.\(^12–14\) By visualizing the coronary arteries, myocardium and their spatial relationships MB could be detected on MDCT,\(^15\) so we used this imaging technique to detect and evaluate the anatomical properties of MB.

**Methods**

We enrolled 607 consecutive patients who underwent MDCT for suspected or known coronary artery disease between July 2006 and April 2007. All patients were in sinus rhythm and received oral nitroglycerin to improve image quality. Patients with an initial heart rate >70 beats/min received 10–40 mg of propranolol prior to MDCT imaging to decrease the heart rate to <70 beats/min. Approximately 60 ml of iodinated contrast agent was injected intravenously at a rate of 5 ml/s, followed by a chaser bolus of 20 ml of normal saline. MDCT data were acquired using a ‘Lightspeed VCT’ 64-channel MDCT scanner (GE Healthcare, Milwaukee, WI, USA). Scan parameters were as follows: a detector collimation of 64×0.625 mm, gantry rotation time of 350 ms, tube voltage of 120 kVp, tube current of 700 mA, and pitch 0.18–0.26. The position of the reconstruction window was initially
placed at 75% of the cardiac cycle, but if necessary, individually adapted in 10% increments and decrements to minimize motion artifacts. Images were transferred to a workstation (AW4.3; GE Healthcare) and evaluated for MB. MB was diagnosed when an intramural segment of a coronary artery was visualized on axial and multiplanar reconstruction images. MB was classified as 1 of 2 types: (1) superficial, in which a myocardial band overlaid the tunneled segment with no deviation of the vessel into the myocardium (Figure 1) or (2) deep, in which the course of the vessel dipped in a U-shaped curve into the myocardium (Figure 2). The thickness and length of the MB were also determined in the short-axis plane and vertical long-axis plane. The minimum diameter of the tunneled artery in diastole was measured. The presence of atherosclerosis in the tunneled segment, and in the arterial segments proximal and distal to the MB, was also evaluated.

Statistical analysis was performed using SPSS version 12.0 (Chicago, IL, USA). Quantitative data are presented as the mean±standard deviation. Mean values were compared by Student’s t-test. A P-value <0.05 was considered significant.

Results

Patient Population
A total of 607 patients underwent MDCT angiography between July 2006 and April 2007. Of these, 39 patients (6.42%) were found to have a MB (1 patient was excluded for analysis because of poor image quality). Of the patients with a MB, 26 (68.4%) were male and 12 (31.6%) were female (mean age, 57.7±10.7 years). Their average body mass index (BMI) was 24.5±3.5 kg/m²; 10 patients (26.3%) had hypertension, 9 (23.7%) had diabetes mellitus, 12 (31.6%) were current smokers and 3 (7.9%) were obese (BMI >30 kg/m²). Most patients (71.1%) presented with chest pain (Table 1). The mean left ventricular ejection fraction was 64.8±7.2% (Table 2).

Figure 1. Visualization of superficial myocardial bridge by multidetector computed tomography. Curved multiplanar reconstruction (A) and axial (B) images show the tunneled segment of the middle of the left anterior descending artery overlaid with myocardium (arrows) and calcified plaque in the segment proximal to myocardial bridge (head of arrow).

Figure 2. Visualization of a deep myocardial bridge by multidetector computed tomography. Curved multiplanar reconstruction (A) and short-axis (B) images show tunneled segment of middle left anterior descending artery overlaid with myocardium (arrow).
Anatomical Features
In 20 patients (52.6%), the MB was located in the mid left anterior descending artery (LAD), in 12 patients (31.6%), it was located in the proximal or distal LAD, and in 3 patients, the MB was located in the ramus intermedius (1 in the right coronary artery, 1 in the obtuse marginal branch, and 1 in the diagonal branch). The superficial type of MB was found in 27 patients (71.1%) and the deep type was found in 11 patients (28.9%). The length of the tunneled artery was a mean 16.34±6.26 mm, from 6.9 mm to 30 mm, and the maximum thickness of myocardial tissue was between 0.5 mm and 3.9 mm, with a mean of 1.84±0.77 mm. The length of the MB was significantly correlated with its thickness (P=0.049) (Figure 3). The minimal luminal diameter in diastole ranged from 1.0 mm to 3.6 mm (mean, 2.20±0.54 mm) (Table 3). The diameter of the proximal segment of the MB was significantly larger than the minimal luminal diameter of the tunneled artery (mean 2.83±0.67 mm and for deep type it was 2.05±1.04 mm. However, there was no significant difference in the thickness of the tunneled artery in the superficial type of MB and deep type (P=0.310). Coronary artery atherosclerosis was found in 20 patients (52.6%). Only 1 patient had small calcified plaques in the intramural segment, and none had plaques in segment distal to the MB. However, the arterial segment immediately proximal to the MB had atherosclerotic plaque in 14 of 38 cases (36.8%). Stents were placed in the stenotic segment proximal to MB in 2 patients. However, there were no significant differences in length, thickness or minimal lumen diameter according to the presence of plaque proximal to the MB (P=0.223, P=0.794 and P=0.260, respectively). Chest pain was the main complaint in 16 (66.7%) of the patients with a superficial MB, whereas all patients with a deep MB had this symptom (P=0.029). Because this study had only a small number of patients with a MB, there were no difference between superficial and deep MB in treadmill test results or the angiographic presentation (P=0.305, P=0.815, respectively). The treadmill test was performed by 15 patients, and 4 had a positive result; they all had a superficial MB, but only 1 had obstructive coronary artery disease, suggesting an ischemia-related MB.

Discussion
The main finding of this study is that the MB can be detected
and evaluated by MDCT. The detection of muscle overlying a segment of a coronary artery on MDCT is helpful for diagnosis and evaluation of MB. The location of the MB in our study was most commonly in the mid-LAD, in concordance with previous reports. Generally, the incidence of MB is between 0.5% and 2.5% angiographically and between 15% and 85% pathologically. In our study, the incidence of MB (6.42%) was higher than reported in an angiographic series, but similar to that reported in some 16-slice MDCT series. However, it was lower than that reported by Konen et al. (30.5%) or Zeina et al. (26%), who used 64-slice MDCT. The difference in incidence might be explained by the different scan parameters and post processing techniques, inclusion or exclusion of borderline cases, and study population. Further study might be needed to evaluate the incidence of MB on MDCT.

In our study, the mean thickness and length of the MB was 1.84 ± 0.77 mm (from 0.5 mm to 3.9 mm) and 16.34 ± 6.26 mm (from 6.9 mm to 30 mm), respectively. The length of the MB significantly correlated with thickness (P = 0.049). However, there was no significant difference in the thickness of the tunneled artery according to MB type (P = 0.31). There was a significant decrease in the diameter of the tunneled artery compared with that of the immediately proximal portion (P < 0.001).

It is known that the tunneled artery of a MB is rarely affected by atherosclerosis and that plaque is more frequently located in the segment just proximal to the MB. The intima beneath the bridged segments always consists of only contractile-type smooth muscle cells, and lacks synthetic-type smooth muscle cells. The synthetic-type smooth muscle cells usually proliferate and produce collagen fibrils and elastic fibers in the intima as atherosclerotic progresses. Myocardial contraction causes increased shear stress in the arterial wall and high shear stress in the tunneled artery is believed to have a protective effect against atherosclerosis, whereas low shear stress in the arterial segments proximal to MB might induce release of endothelial vasoactive agents leading to increased atherosclerosis. In our study, coronary artery atherosclerosis was found in 20 patients (52.6%). Although most of the intramural segments were free of coronary wall lesions, the arterial segment immediately proximal to the MB had atherosclerotic plaque in 14 of 38 cases (36.8%). Our study also confirms the association of atherosclerotic changes with MB, as in previous studies.

There were no significant differences in length, thickness or minimal lumen diameter according to presence of plaque proximal to the MB (P = 0.223, P < 0.794 and P = 0.260, respectively).

The relationship between MB and symptoms is still unclear. Generally, MB is an incidental finding and is not considered a normal variant or a benign coronary anomaly. Most of the reported cases of MB had no clinical consequences, and follow-up studies of patients with MB have shown generally good prognosis even in patients with >50% systolic compression. However, it has been reported that MB may be responsible for flow disturbances, myocardial ischemia and infarction, arrhythmia and sudden death. In our study, 3 patients were thought to have ischemia-related MB. MB is also a problem during bypass surgery. Because of these problems associated with MB, detection and evaluation are important. On CAG, MB is an indirect finding of systolic compression of the tunneled segment (milking effect) and in addition, only the deep type of MB may be more apparent. It is common for MB to be under diagnosed angiographically and its incidence with this imaging modality is lower than its pathological incidence.

In our study, 11 patients underwent CAG and MB was detected in only 5 patients, including 3 with a superficial MB and 2 with a deep MB. Recently, MDCT was proposed as providing reliable and noninvasive evaluation of the coronary arteries and cardiac anomalies. In several studies, MDCT has shown the presence, location, length, thickness and anatomical features precisely. In our study, MDCT was useful tool for detecting and evaluating MB. However, this study had some limitations. First, it was done by retrospective review of MDCT findings, so the prevalence of MB may have been underestimated. Also, the subjects in this study had suspected or known coronary artery disease, and so were not representative of the general population. Third, there was a lack of pathological, symptomatic correlations because MB was diagnosed by MDCT. Although there was a difference in clinical presentation between the superficial and deep types of MB, we did not perform sufficient evaluation of other causes of chest pain, including gastrointestinal studies. Finally, we used only the diastolic phase, so we could not evaluate the presence or degree of systolic compression of the tunneled artery or the difference between the appearance of the bridge in systole and diastole.

In summary, we describe the incidence of the MB and its anatomical properties on MDCT, which is a useful and noninvasive tool for evaluating this anatomical variant.

References


