Myocardial Bridging in Taiwan: Depiction by Multidetector Computed Tomography Coronary Angiography

Yu-Dong Chen, Mei-Han Wu, Ming-Huei Sheu,* Cheng-Yen Chang

Background/Purpose: Myocardial bridging (MB) is a condition in which a segment of the major epicardial coronary artery is tunneled within and surrounded by the myocardium. This condition has been linked to severe complications. The aim of this study was to evaluate the incidence of MB in Taiwanese subjects examined with electrocardiogram-gated, 16-slice, multidetector computed tomography (MDCT) coronary angiography, as well as to determine the location, depth, and length of the bridged segments and the concomitant atherosclerosis of MB.

Methods: From August 2004 to May 2005, 276 consecutive subjects referred to our department for MDCT coronary angiography were enrolled in the study after written informed consent was obtained from each participant.

Results: Twenty-four subjects (8.7%) had at least one coronary segment that was completely surrounded by myocardium. Patients ranged in age from 27 to 76 years, with an average of 54 ± 12 years. Thirty coronary segments were found to have MB. The most common location of MB was in segment 7, which accounted for 14 coronary segments (46.7%) of the total number of bridged segments; left anterior descending artery (LAD) segments accounted for 23 (76.7%); and right coronary artery and left circumflex artery segments accounted for three (10%) and two (6.7%), respectively. The length of bridged segments ranged from 5.2 to 50.6 mm, with an average length of 24.6 ± 11.8 mm, and the depth of the bridged segments ranged from 0.5 to 9.1 mm, with an average depth of 3.65 ± 1.89 mm. Two bridged segments (6.7%) had concomitant atherosclerosis; these were located in segment 7 (24.0 mm long and 6.10 mm deep) and segment 8 (27.1 mm long and 7.0 mm deep). Bridged segments with concomitant atherosclerosis were deeper, but not longer, compared with bridged segments without concomitant atherosclerosis (p < 0.05).

Conclusion: Electrocardiogram-gated MDCT is an effective noninvasive tool for evaluating MB in a clinical setting. The most common location of MB was in the LAD, especially in segment 7. Bridged segments with concomitant atherosclerosis were deeper, but not longer, compared with bridged segments without concomitant atherosclerosis. [J Formos Med Assoc 2009;108(6):469–474]

Key Words: coronary angiography, multidetector computed tomography, myocardial bridging, tunneled artery
Myocardial bridging (MB) is a congenital coronary abnormality that is defined as a segment of a major epicardial coronary artery that tunnels intramurally through the myocardium beneath the muscle bridge. This was first described angiographically by Porstmann and Iwig in 1960. Patients should be thoroughly evaluated for potential MB because it may cause serious complications.

Coronary catheter angiography is the current imaging reference standard for the diagnosis of MB. The diagnosis has also been made using intravascular ultrasound and intracoronary Doppler ultrasound. All of these procedures are invasive. Additionally, interpretation of angiography findings requires an experienced eye, and only the deep type of bridges may be apparent with angiography. Multidetector computed tomography (MDCT) is a noninvasive imaging tool for evaluating coronary artery stenosis and abnormalities, including MB. With this technique, it is possible to see clearly the intramyocardial location of the involved coronary arterial segment.

The aim of this study was to evaluate the incidence of MB in Taiwanese patients examined with electrocardiogram-gated (ECG-gated), 16-slice, MDCT coronary angiography, as well as to determine the location, depth, and length of the bridged segments and the concomitant atherosclerosis of MB. Detailed and crucial anatomical information about MB cannot be obtained with conventional coronary angiography.

**Patients and Methods**

From August 2004 to May 2005, 276 consecutive subjects who were referred to our department for MDCT coronary angiography were enrolled after written informed consent was obtained. All subjects were informed about the risks of contrast medium administration and the possible risks of radiation exposure.

The subjects were imaged in the supine position, and all image acquisition was performed with a 16-slice MDCT scanner (Sensation 16; Siemens Healthcare, Erlangen, Germany). The scan parameters were as follows: 1 mm slice thickness, 0.75 mm detector collimation, 420 ms rotation time, 3.4 mm/rotation table feed, 600 mA and 120 kV tube current. The scanning range covered from 1 cm below the carina to the cardiac apex in a single breath-hold. Non-ionic contrast medium was administered as follows: 350 mg/mL iodine, at a flow rate of 4–5 mL/s in a total volume of 70–100 mL followed by saline. Scanning delay was determined according to the automatic bolus tracking, which was dependent on the region of interest on the ascending aorta. All subjects were instructed to maintain an end inspiration breath-hold during which the CT data and ECG trace were acquired.

Image reconstruction was done using the retrospective ECG-gated method; data sets were acquired at multiple phases of the R-R cycle. Images taken during the R-R cycle with the smallest motion artifacts were post-processed at workstations (Siemens Leonardo; Siemens Healthcare) to create multiplanar reconstruction (MPR) and curved MPR images. These were used to depict MB on at least two planes: one parallel and the other perpendicular to the course of the vessel. When part of a coronary artery was completely surrounded by myocardium, it was defined as MB.

Evaluation of the coronary arteries was performed according to the classification of the American Heart Association: right coronary artery (RCA, segments 1–4), left main coronary artery (LM, segment 5), left anterior descending coronary artery (LAD, segments 6–10), and left circumflex coronary artery (LCX, segments 11–15). The location of MB was recorded according to the classifications described above. The depth of MB was measured from transaxial images (i.e. perpendicular to the course of the vessel). The length of MB was determined by curved MPR images (i.e. parallel to the course of the vessel). Atherosclerosis of MB was evaluated by MPR and curved MPR images.

The location, depth, and length of the bridged segment, as well as the concomitant atherosclerosis, were recorded using the reconstruction and reformation techniques described above. CT data
were analyzed by three dedicated cardiovascular radiologists.

Results

All MDCT coronary angiography examinations were performed without complications. Image quality was good, and all bridged segments were assessable. Twenty-four subjects (8.7%) had at least one coronary segment completely surrounded by myocardium (Figure 1), including 18 men (6.5%) and six women (2.2%). Subject ages ranged from 27 to 76 years, with an average age of 54 ± 12 years.

Thirty coronary segments showed MB. The most common location of MB was in segment 7, which accounted for 14 coronary segments (46.7%) of the total number of bridged segments; LAD segments accounted for 23 (76.7%), and RCA and LCX segments accounted for three (10%) and two (6.7%), respectively. Two bridged segments (6.7%) were in the ramus intermedius branch, and no MB was observed in the LM. The location, depth, and length of the bridged segments and prevalence of MB in each coronary segment are presented in the Table and Figure 2.

Bridging of more than one segment, also known as multisegment bridging, occurred in four subjects (1.4% of the total), and accounted for 16.7% of those with bridging. In two of the four subjects with multisegment bridging, contiguously bridged segments were found in segments 7 and 8.

The length of the bridged segments ranged from 5.2 to 50.6 mm, with an average length of 24.6 ± 11.8 mm. The depth of the bridged segments ranged from 0.5 to 9.1 mm, with an average depth of 3.65 ± 1.89 mm. Two bridged segments (6.7%) had concomitant atherosclerosis (Figure 3); these were located in segment 7 (24.0 mm long and 6.10 mm deep) and segment 8 (27.1 mm long and 7.0 mm deep). Bridged segments with concomitant atherosclerosis were deeper, but not longer, compared with bridged segments without concomitant atherosclerosis ($p < 0.05$).

Discussion

MB of coronary arteries in systole historically has been considered an incidental finding; however, now it has been linked in selected cases to more severe complications, including acute myocardial infarction,9–11 paroxysmal supraventricular tachycardia,10 ventricular tachycardia,9,12,13 exercise-induced atrioventricular conduction block14 and sudden death.12,15

The reported prevalence of bridging varies in pathological and angiographic studies. Autopsy reports have found a mean frequency of MB of 25% (range, 5–86%).12,16–18 Although all major epicardial coronary arteries may be affected, LAD involvement is the most common. The depiction rate of MB in conventional coronary angiography studies is 0.5–4.5%.19,20 The large discrepancy between the prevalence of MB in autopsy and conventional coronary angiography studies indicates the absence of an accurate reference imaging modality.

Conventional coronary angiography provides visualization that is limited to the vessel lumen, which limits investigators to relying on indirect

Figure 1. A 16-slice, multidetector computed tomography, contrast-enhanced coronary angiography of a 58-year-old woman with myocardial bridging, which clearly shows the intramyocardial course of the first obtuse marginal branch of the left circumflex artery (arrows).
signs, and this method is therefore likely to underestimate the prevalence of MB.21 Even though systolic compression and the milking effect are considered diagnostic,2 the signs are rather insensitive in shallow variants of MB that demonstrate only minimal or no systolic compression.12,22 Similarly, the step down-step up phenomenon may be absent in superficial variants of MB.

The detection rate of MB in the present Taiwanese group was 8.7%, which is higher than that reported previously in cardiac catheter angiography studies (0.5–4.5%).19,20 Compared with conventional coronary angiography, MDCT enables direct visualization of the coronary arteries, including the surrounding tissue, and thus allows the depiction of tunneled segments, even

<table>
<thead>
<tr>
<th>Location of MB</th>
<th>Number of bridged segments (n = 30)</th>
<th>Prevalence* (%)</th>
<th>Length (mm)</th>
<th>Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal RCA (segment 1)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Middle RCA (segment 2)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Distal RCA (segment 3)</td>
<td>2</td>
<td>0.72</td>
<td>16.2 ± 9.7</td>
<td>4.25 ± 0.07</td>
</tr>
<tr>
<td>Posterior descending branch (segment 4)</td>
<td>1</td>
<td>0.36</td>
<td>17.6</td>
<td>1.73</td>
</tr>
<tr>
<td>Left main coronary artery (segment 5)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Proximal LAD (segment 6)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Middle LAD (segment 7)</td>
<td>14</td>
<td>5.1</td>
<td>21.1 ± 7.3</td>
<td>3.60 ± 1.47</td>
</tr>
<tr>
<td>Distal LAD (segment 8)</td>
<td>7</td>
<td>2.5</td>
<td>22.1 ± 10.8</td>
<td>3.12 ± 2.39</td>
</tr>
<tr>
<td>First diagonal branch (segment 9)</td>
<td>2</td>
<td>0.72</td>
<td>25.7 ± 0.4</td>
<td>4.45 ± 0.92</td>
</tr>
<tr>
<td>Second diagonal branch (segment 10)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Proximal LCX (segment 11)</td>
<td>1</td>
<td>0.36</td>
<td>41.2</td>
<td>2.8</td>
</tr>
<tr>
<td>First obtuse marginal branch (segment 12)</td>
<td>1</td>
<td>0.36</td>
<td>55.4</td>
<td>2.31</td>
</tr>
<tr>
<td>Middle LCX (segment 13)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Second obtuse marginal branch (segment 14)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Distal LCX (segment 15)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Posterior left ventricular branch</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Ramus intermedius branch</td>
<td>2</td>
<td>0.72</td>
<td>45.1 ± 7.8</td>
<td>6.55 ± 3.61</td>
</tr>
</tbody>
</table>

*Prevalence was defined as MB detected for each specified segment/numbers of segments studied for each specified segment. MB = myocardial bridging; RCA = right coronary artery; LAD = left anterior descending artery; LCX = left circumflex artery.
when MB is short and shallow. The difference in
the depiction rate of MB between conventional
coronary angiography and MDCT was determined
to have a significant relationship to length, depth,
and degree of systolic compression. Additionally, LAD segments accounted for 76.7% of the
total number of bridged segments, with the most common location of MB being in the middle LAD (46.7%). RCA (10%) and LCX (6.7%) segments accounted for fewer bridged segments in our study. These results are in agreement with autopsy findings.

Quantitative coronary angiography, intracoronary Doppler ultrasound, and intravascular ultrasonography have documented a characteristic diastolic flow disturbance. The degree of coronary obstruction caused by MB depends on factors such as the location, depth, and length of the muscle bridge and the degree of cardiac contractility. The likelihood of ischemia also increases with the intramyocardial depth of the tunneled segment. In a recent MDCT study, the depth, but not the length, of the tunneled segment correlated significantly with the percentage of systolic compression.

MDCT coronary angiography enabled us to determine morphological characteristics such as the length and depth of the tunneled segments. Multiplanar and curved planar reformations were used to depict MB in at least two planes: one parallel and the other perpendicular to the course of the vessel. The length and depth of the tunneled segments may be measured accurately; these would be more difficult to measure with indirect visualization techniques using conventional coronary angiography.

Regarding the occurrence of atherosclerotic plaques in the tunneled coronary segment, previous studies have shown that the tunneled segment is affected rarely by atherosclerosis, unlike the epicardial segments, in which atherosclerotic plaques are found frequently. It has been postulated that the intramyocardial course of the coronary artery has a protective effect on the development of atherosclerosis at the site of the myocardial bridge. Recent studies have found that the segments proximal to the bridge are narrowed significantly, whereas the tunneled segment itself is free of atherosclerotic lesions. Increased wall shear stress proximal to the bridging segment is thought to be a predisposition for the development of atherosclerosis. This phenomenon has now been confirmed by the present Taiwanese study, in which atherosclerotic lesions were found in the coronary arteries proximal to the bridge, whereas the tunneled segment was spared (Figure 3). MB predisposes the development of atherosclerosis in the coronary artery segment proximal to the bridge. Furthermore, in our study, the two bridged segments with concomitant atherosclerosis were deeper, but not longer, than the bridged segments without concomitant atherosclerosis.

MDCT is an effective noninvasive tool for evaluating MB in a clinical setting. The incidence of MB examined with 16-slice MDCT in the present study was 8.7%, which is higher than with conventional coronary angiography. The most common location of MB is in the LAD, especially in segment 7, and the results are in agreement with findings in autopsy reports. Bridged segments with concomitant atherosclerosis were deeper, but not longer, than bridged segments without concomitant atherosclerosis.
References

1. Porstmann W, Iwigi J. Intramural coronary vessels in the angiogram. Fortschr Geb Rontgenstr Nuklearmed 1960; 92:129–33. [In German]


