Coronary Plaque Stabilization Followed by Color Code Plaque\textsuperscript{TM} Analysis With 64-Slice Multidetector Row Computed Tomography

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A 61-year-old woman with hypercholesterolemia, hypertension and diabetes mellitus was referred to hospital for the evaluation of chest pain at rest. Eccentric 50% stenosis in the proximal right coronary artery was detected by 64-slice multidetector row computed tomography (MDCT). The plaque morphology was considered as soft by Color Code Plaque\textsuperscript{TM} (CCP) analysis. Seven days after MDCT, chest pain continued and transient ST-elevation was detected on the II-lead ECG monitor during echocardiography. Therefore, emergency coronary angiography was performed and confirmed the 50% stenosis as shown on MDCT. Her disease was diagnosed as vasospastic angina. For the purpose of plaque stabilization, lipid-lowering therapy with atorvastatin was instituted and her symptoms improved. After 11 months, serum total cholesterol and LDL-cholesterol levels were reduced. A second MDCT was performed and plaque morphology had changed from soft to intermediate. Cross-sectional multiplanar reconstruction of MDCT images indicated reduction of total vessel area, expansion of the lumen area and improvement of the remodeling index at the site of stenosis. The lipid-lowering therapy contributed to plaque stabilization, and CCP analysis by noninvasive MDCT was useful for plaque characterization. This case suggests that differences between vulnerable and stable plaques can be classified using MDCT to predict acute coronary syndrome. (Circ J 2009; 73: 772–775)

Key Words: Plaque stabilization; 64-Slice multidetector row computed tomography; Statins

As an alternative to invasive coronary angiography (CAG) or intravascular ultrasound (IVUS), noninvasive 64-slice multidetector row computed tomography (MDCT: 64×0.625 mm collimation) with retrospective ECG-gated image reconstruction permits coronary artery visualization and the detection of coronary artery stenoses with high accuracy.\textsuperscript{1,2} Additionally, because not only the vessel lumen but the vessel wall and adjacent tissue can be visualized by this modality, MDCT might be useful for characterizing coronary plaque morphology by determining its tissue density\textsuperscript{3–6} and for assessment of coronary remodeling.\textsuperscript{7} We propose a new method, Color Code Plaque\textsuperscript{TM} (CCP) analysis (GE Healthcare, Waukesha, WI), which analyzes each pixel value of the computed tomography (CT) images as opposed to the conventional region of interest. CCP measures the CT number of plaque for each pixel, and codes them with several color ranges that can be easily modified by changing the CT number criteria.

Case Report

A 61-year-old woman with hypercholesterolemia, hyper-
tension and diabetes mellitus was referred to hospital for the evaluation of chest pain at rest. At the first medical examination, she was treated with amlopropine 5 mg/day, nicorandil 15 mg/day and pravastatin 10 mg/day.

MDCT (VCT; GE Healthcare, detector collimation 64×0.625 mm, 0.35 s/rotation) was performed to evaluate the coronary artery disease and the field-of-view was set to 186 mm with a matrix of 512×512 (0.36×0.36 mm/pixel). An approximately eccentric 50% stenosis in the proximal right coronary artery (RCA) was detected in the volumerendering image and multiplanar reconstructions (MPR) (Figures 1A, B). At the 3 sites of maximal stenosis, distal and proximal 2 mm apart, cross-sectional MPR images were acquired (Figure 1D Left) and CCP analysis was also done at those sites (Figures 1C, D Right).

The color patterns of CCP were easily modified to our preset color codes by changing the CT number (soft plaque: yellow to emerald-green –40–50 HU; intermediate plaque: blue 50–120 HU; enhanced vessel lumen: transparent 120–500 HU; calcified plaque: red 500–2,000 HU) according to Schroeder’s criteria? Approximately two-thirds of the plaque burden was light-green (0–25 HU) and one-third was yellow (~40–0 HU) at these sites. We diagnosed this plaque as soft (yellow to emerald-green code) according to our original CCP pattern.

Seven days after MDCT, chest pain was triggered accidentally during echocardiography, continued for approximately 5 min and transient ST-elevation was apparent on the II-lead ECG monitor. Therefore, acute coronary syndrome (ACS) was considered and emergency CAG was performed, which revealed the approximately 50% stenosis in the proximal RCA (Figure 2), as on MDCT. Her disease...
was diagnosed as vasospastic angina and as the stenosis was not so significant percutaneous transluminal coronary angioplasty was not done. Diltiazem 200 mg/day and aspirin 81 mg/day were administered for prevention of coronary spasm. For lipid-lowering therapy (plaque stabilization), pravastatin 10 mg/day was changed to atorvastatin (strong statin) 10 mg/day and alimentotherapy and ergotherapy were performed in parallel. These treatments were effective for vasospastic angina. After 11 months, serum total cholesterol and LDL-cholesterol levels had improved from 220 to 158 mg/dl and from 119 to 85 mg/dl, respectively, but the HDL-cholesterol level had not (from 64 to 57 mg/dl).

Repeat MDCT examination was performed (Figures 3A–D). Cross-sectional vessel area, lumen area and remodeling index at the site of maximal stenosis before and after lipid-lowering therapy were compared and the respective values had changed from 21.0 to 18.3 mm$^2$, 3.6 to 5.7 mm$^2$ and 1.29 to 1.07. At the same sites, approximately 50% of the plaque burden was blue coded and the other half was emerald-green (Figure 3D).

The plaque morphology changed from soft to intermediate, according to our original CCP pattern. Additionally, the change in both plaque volume and percent volume, which were measured with CCP before and after lipid-lowering therapy, were measured as follows. The volume study using CCP was evaluated by 2 observers who were unaware of the results. Moreover, the volumes of each vessel and plaque were measured 3 times by each observer. For comparison of the 2 images (ie, before and after the lipid-lowering therapy), exact matching of the plaque location was ensured by using the origins of small side branches as landmarks. The measured values were averaged and are shown in Table. After lipid-lowering therapy, the volume and the percent volume of soft plaques had reduced and those of intermediate plaques had slightly increased. Repeat CAG might not be needed.

**Discussion**

Coronary spasm contributes to the occurrence of myocardial ischemia. There might be occult atherosclerotic lesions at the sites of focal coronary spasm and the plaque

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**Figure 1.** Right coronary artery findings of multidetector row computed tomography (CT) before lipid-lowering therapy. (A) Volume-rendering image (right anterior oblique view). (B) Curved-multiplanar reconstruction (MPR) image. Higher power magnification corresponding to the area outlined by the box in (A). (C) Curved-MPR images of the Color Code Plaque$^\text{TM}$ (CCP) at the same site (B). Color code pattern is as follows, soft plaque: yellow –40–0 HU, light green 0–25 HU, emerald-green 25–50 HU; intermediate plaque: blue 50–120 HU; enhanced vessel lumen: transparent 120–500 HU; calcified plaque: red 500–2,000 HU. (D) Cross-sectional images of curved-MPR (Left side) and those of CCP (Right side) at the dotted lines (a–c). Reference site (arrowhead) was 9 mm proximal from slice (a). Lumen CT value of the reference site was 303 HU. Plaque volumes were measured between the origins of the small side branches used as landmarks (double arrow).

**Figure 2.** Right coronary angiogram after intracoronary arterial injection of isosorbide dinitrate. (A) Left anterior oblique view 30º, (B) right anterior oblique view 30º. Arrow indicates 50% stenosis in the proximal site of the right coronary artery.
associated with focal coronary spasm might not be calcified. Moreover, if the plaque is vulnerable, it is well known that coronary spasm will cause it to rupture and precipitate the onset of ACS. Vulnerable plaque is characterized histologically as a large lipid pool covered by a thin fibrous cap. However, it is impossible for CT or IVUS to evaluate the latter, whereas MDCT can precisely detect the lipid pool and measure the CT values of the plaque.

On gray-scale MDCT images, the measurement of plaque CT values surrounded by a region of interest is commonly performed for evaluation of plaque morphology. Komatsu et al reported a method of evaluating plaque morphology with 8-slice MDCT, called ‘Plaque map’, which measures the CT numbers of the included plaque for each pixel at each cross-sectional vessel and codes them using 14 color ranges. ‘Plaque map’ images have been compared with the findings of IVUS and the sensitivities of soft, intermediate and calcified plaque are 92%, 87% and 89%, respectively.

Based on ‘Plaque map’, we propose original CCP, in which the color codes are divided into 6 modified ranges according to Schroeder’s criteria. Additionally, the temporal and spatial resolutions of the current 64-slice MDCT are remarkably improved over that of 8-slice MDCT. Therefore, the images obtained with 64-slice MDCT are drastically improved and we believe that the accuracy of plaque diagnosis is correct more often with CCP than with ‘Plaque

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**Table. Vessel and Plaque Volumes Measured by Color Code PlaqueTM Before and After Lipid-Lowering Therapy**

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>Date</td>
<td>6/1/2006</td>
<td>11/12/2006</td>
</tr>
<tr>
<td>Total vessel volume: mm³(%)</td>
<td>266/(100)</td>
<td>253/(100)</td>
</tr>
<tr>
<td>Vessel lumen volume: mm³(%) 120–500 HU</td>
<td>128/(48.2)</td>
<td>142/(56.1)</td>
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<tr>
<td>Calcified plaque volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red area 500–2,000 HU</td>
<td>1/(0.4)</td>
<td>1/(0.4)</td>
</tr>
<tr>
<td>Intermediate plaque volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue area 50–120 HU</td>
<td>54/(20.3)</td>
<td>61/(24.1)</td>
</tr>
<tr>
<td>Soft plaque volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emerald-green area 25–50 HU</td>
<td>27/(10.1)</td>
<td>22/(8.7)</td>
</tr>
<tr>
<td>Light-green area 0–25 HU</td>
<td>27/(10.1)</td>
<td>18/(7.1)</td>
</tr>
<tr>
<td>Yellow area –40–0 HU</td>
<td>29/(10.9)</td>
<td>9/(3.6)</td>
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Percent volume of each vessel and plaque shown in parentheses. Vessel and plaque volumes were measured at the same sites between the origins of the small side branches used as landmarks (double arrow in Figures 1C, 3C).
map’. In the present case, before CAG, mild stenosis was diagnosed and plaque morphology was diagnosed as soft by CCP, because it contained very low CT values (–40–0 HU). Therefore, we administered an antispastic drug (diltiazem) and a statin for plaque stabilization and pleiotropic effects to prevent plaque rupture and ACS.

CCP with non-invasive 64-slice MDCT is a modality available for assessment of atherosclerotic plaque morphology and for the temporal evaluation of the volume and percent volume of each plaque (soft, intermediate and calcified) before and after medication.

There are limitations to the use of CCP. As the concept is based on the CT value, the plaque CT value is influenced by contrast media density in the vessel lumen, calcium blooming effects and motion artifacts. In the present case, the evaluation of plaque with CCP was considered to be correct, because both lumen CT values (approximately 300 HU) at the reference sites of the first and second CCP examination were similar and only slightly affected by those of the plaques (Figures 1, 3).

It might prove difficult to distinguish soft plaque and thrombus in the acute stage of ACS, because the CT values of thrombus are similar to those of soft plaque. Additionally, if the boundary CT value between soft and intermediate plaques is changed, the color coding of the plaque might be different.

CCP will not equal the versatility or quantitative accuracy of IVUS-based imaging techniques anytime soon. It is anticipated that future generations of MDCT will have better spatial and temporal resolutions and hence improved diagnostic accuracy, and then the CCP images might be approximately equal to those of invasive integrated backscatter-IVUS and virtual histology-IVUS.

References