Diagnostic Accuracy of 64-slice Dual-source Computed Tomography in the Detection of Coronary Artery Stenosis based on Patient Heart Rate and Calcium Scores

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Purpose: To assess the diagnostic accuracy of dual-source computed tomography (DSCT) in the detection of coronary artery stenosis (CAS) based on patient heart rate and calcium scores.

Materials and Methods: This study included 102 patients (46 male, 56 female; mean age 64.1 ± 10.6 years; age range 37–92 years) with chest pain and who underwent DSCT as well as invasive coronary angiography. Patients were classified into three groups according to mean heart rate (<70 bpm, 70–90 bpm, and >90 bpm) and also classified in three groups according to Agatston calcium scores (<100, 100–400, and >400).

Results: For patients with a mean heart rate < 70 bpm, the sensitivity, specificity, PPV, NPV, and diagnostic accuracy of DSCT on a per-vessel basis were 98.5%, 98.2%, 93.6%, 99.1%, and 97.9%, respectively, for 70–90 bpm; and 91.7%, 97.9%, 88.5%, 96.7%, and 95.7%, respectively, for >90 bpm. For calcium scores <100, the sensitivity, specificity, PPV, NPV, and diagnostic accuracy of DSCT on a per-vessel basis were 97.2%, 99.0%, 97.0%, 99.3%, and 98.6%, respectively, for calcium scores 100–400, and 95.8%, 97.0%, 87.4%, 97.2%, and 95.6%, respectively, for calcium scores >400.

Conclusion: DSCT showed a high diagnostic accuracy and negative predictive value, regardless of heart rate and calcium score.

Index words: Tomography, X-Ray Computed
Coronary Angiography
Coronary Artery Disease
Recently, coronary computed tomography angiography (CCTA) has been shown to accurately determine high negative predictive value in the diagnosis of significant coronary artery stenosis (CAS). Clinical studies comparing the diagnostic value of 64-slice multidetector computed tomography (CT) to invasive coronary angiography (ICA) have shown that CCTA has a high negative predictive value ranging from 97 to 100% on a per-patient basis (1–9). CCTA has allowed the reliable exclusion of significant coronary artery stenosis and effectively obviated further invasive workup with ICA.

Despite the promising results of 64-slice multidetector CT, there are some diagnostic limitations due to poor image quality, as a result of artifacts caused by an elevated heart rate and vessel wall calcification (5, 8–10). Therefore, beta-blockers are routinely used to reduce the heart rate to a level of 65 beats/min or less in order to decrease the motion artifact in patients with fast heart rates and arrhythmias. The recently introduced dual-source CT (DSCT) uses two X-ray tubes with corresponding detectors to achieve an improved temporal resolution of 83 ms, which is a major improvement over single-source CT systems. DSCT has also increased the robustness of the examination in patients with fast and arrhythmic heart rates (1, 11). As a result, the diagnostic accuracy of DSCT for detecting coronary artery disease is greater than that of 64-slice multidetector CT scanning.

First, feasibility studies reported that the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of DSCT in the detection of coronary artery stenoses on a per-patient basis were 95–100%, 83–90%, 74–89%, and 98–100%, respectively. The detection of stenosis was found to be >50% on a per-segment basis, while these same measurements were 88–95%, 92–99%, 68–81%, and 97–99%, respectively for DSCT (1, 12–18).

Despite the considerable advances in scanner technology and image postprocessing techniques, it has proven difficult in practice to obtain good coronary artery images when the heart rate is above 90 bpm and the calcium score is high [above 400]. There is increasing interest in the diagnostic accuracy of DSCT for CAS in the absence of a beta-blocker when data is subdivided according to heart rate and calcium score (13–18). Although a few reports have been published concerning the diagnostic accuracy as it relates to heart rate and calcium scoring, these papers classified groups according to mean heart rate (<70 bpm and ≤70 bpm) (17, 18). The purpose of our study was to evaluate the diagnostic accuracy of CCTA using DSCT in patients with suspected coronary artery disease by evaluating the effect of heart rate and calcium scoring in the diagnosis of significant CAS by DSCT.

**Materials and Methods**

**Study Population**

This study was performed prospectively after obtaining approval from the ethics committee of our institution. One hundred thirteen patients who underwent CCTA and ICA and seen between September 2007 and June 2009 were included in the study. All patients had symptoms of new or chronic angina without evidence of acute infarction and were referred for invasive angiography. We excluded 11 patients who had a history of coronary bypass surgery (n = 1), stent insertion (n = 6), and coronary anomalies (n = 4). One hundred and two patients (46 male, 56 female; mean age, 64.1 ± 10.6 years; age range, 37–92 years) were ultimately included in this study. The mean body mass index (BMI) [weight in kilograms divided by the square of height in meters] was 24.5 ± 2.7 [range 16.2–32.3] (Table 1). No beta-blockers were administered in preparation for the scans. The mean time interval between CCTA and ICA was 14 ± 15 days [range 0–70], with CCTA performed primarily in most patients.

**DSCT Examination**

All CT examinations for the evaluation of the coronary arteries were performed with a 64-slice DSCT scanner (Somatom Definition, Siemens Medical Systems, Germany).

### Table 1. Patient Demographics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean heart rate (bpm)</td>
<td>78.5 ± 16.7</td>
</tr>
<tr>
<td>Mean Agatston score</td>
<td>227.4 ± 420.8</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>64.1 ± 10.6</td>
</tr>
<tr>
<td>Male gender</td>
<td>46 (45%)</td>
</tr>
<tr>
<td>Risk factors</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>58 (57%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>25 (25%)</td>
</tr>
<tr>
<td>Smoking</td>
<td>25 (25%)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>30 (29%)</td>
</tr>
<tr>
<td>Obesity (BMI ≥30 kg/m²)</td>
<td>4 (4%)</td>
</tr>
<tr>
<td>Previous CAD</td>
<td>4 (4%)</td>
</tr>
<tr>
<td>Family history of CAD</td>
<td>3 (3%)</td>
</tr>
</tbody>
</table>

Note.—bpm = beats per min, BMI = body mass index, CAD = coronary artery disease

Values are expressed as mean ± SD or absolute patient numbers (%).
Non-contrast CT scanning for calcium scoring was performed from 1 cm below the tracheal bifurcation to the diaphragm in a cranio-caudal direction. Non-contrast CT scans were obtained with a 0.6-mm collimation, a rotation time of 0.33 msec tube voltage of 120 kV, tube current of 100 mAs per rotation on both tubes, and a pitch of 0.3–0.39 [depending on heart rate]. The scan time was 5.7–8.1 seconds for a single breath hold.

Before CCTA was performed, all patients received a single 0.6-mg dose of sublingual nitroglycerin (Myoungmoon, Seoul, Korea). CCTA was performed using a triphasic injection protocol. Bolus tracking was performed in the ascending aorta, with an additional scan delay of 7 seconds used for timing. In the first phase, a 50 mL bolus of 370 mg I/mL iopromide contrast media (Ultravist; Schering, Erlangen, Germany) was injected into an antecubital vein at a flow rate of 4–5 mL/s. In the second phase, 50 mL of mixed contrast agent and saline (7:3 or 6:4) was injected at the same flow rate, followed by a 40 mL saline chasing bolus administered using an autoinjector (Stellant; Medrad, USA). The patient held his or her breath at mild inspiration. The mean scan time was 10 seconds (range 7–12 seconds). The tube voltage was 100 kV or 120 kV for both tubes. The heights and weights of all patients were measured, and BMI was calculated. If BMI was 26 kg/m² or less, 100 kV was used; if BMI was over 26 kg/m², 120 kV was used (4, 17, 19). The full tube current was applied for the cardiac phase between 30% and 80% of the cardiac cycle if the heart rate was less than 90 beats per minute (bpm). The current was full between 10% and 100% of the cardiac phase between 30% and 80% of the cardiac cycle if the heart rate was more than 90 bpm between 10% and 100% of the cardiac cycle if the heart rate was more than 90 bpm, because good images could be obtained during the systolic phase for most patients with a fast heart rate. The gantry rotation time was 0.33 seconds, while the pitch was 0.3–0.4, depending on heart rate. Using a medium soft convolution kernel and a mono-segment reconstruction algorithm that uses data from quarter rotations of both detectors, 1 mm axial images were reconstructed for the entire cardiac cycle, with reconstruction intervals obtained in 10% steps. This also allowed for the evaluation of cardiac function.

The effective CCTA dose was estimated using a method proposed by the "European Working Group for Guidelines on Quality Criteria in CT" (20). The effective dose was derived from a product of the dose-length product, with a conversion coefficient for the chest as the investigated anatomic region (21).

**Image Reconstruction**

A retrospective gating technique and a mono-segment reconstruction algorithm were used for image reconstruction. In each patient, images were reconstructed at 60% and 70% (end-diastole), as well as at 30%–35% (systole) of the R-R interval. If deemed necessary, additional images were reconstructed in 10% steps of the R-R interval within the full tube current window. Axial images with a slice thickness of 0.75 mm and at increments of 0.5 mm, were reconstructed using a medium soft convolution kernel (B25f). All reconstructed images were transferred to a dedicated workstation (Leonardo, Siemens Medical Solutions, City, Country), equipped with dedicated cardiac post-processing software (Syngo Circulation, Siemens Medical Solutions).

**Image Analysis and Invasive Coronary Angiography**

The mean Agatston score was calculated for each patient using semi-automated software [Syngo Calcium Scoring, Siemens Medical Solutions]. For CCTA analysis, coronary arteries were segmented according to the guidelines of the American Heart Association (22). The right coronary artery (RCA) was defined to include segments 1–5. The left main and left anterior descending arteries (LM-LAD) were defined to include segments 6–11, and the left circumflex artery (LCX) was defined to include segments 12–16. The ramus intermedius was designated as segment 17 if present. A coronary artery analysis was performed in all vessels with diameters as low as 1.5 mm, including those vessels distal to complete occlusions. Diameter measurements were performed with an electronic caliper tool. The vessel segments on ICA were evaluated by quantitative coronary analysis (QCA) (CAAS; Piemedical Imaging, Maastricht, Netherlands) by an experienced observer who was blinded to the results of the DSCT coronary angiography. All stenoses were graded in 2 projections by a densitometrical analysis via QCA software and recorded stenoses based on their location in the body. Coronary artery segments were defined according to the same guidelines mentioned above (22). In this analysis, significant stenosis was defined as a diameter reduction of >50%.

Two experienced radiologists viewed the images independently without clinical results using 1-mm reconstructed axial images, oblique multiplanar reformation images (2 chamber, 4 chamber, short axis), curved multiplanar reformations (cMPR), axial views of cMPR, maximal intensity projection images, and the three-di-
A dimensional volume rendering technique (VRT). The image quality of each coronary segment was assessed semi-quantitatively on a four-point ranking scale, as previously published (4): 1, excellent (no artifacts, unrestricted evaluation); 2, good (minor artifacts, good diagnostic quality); 3, adequate (moderate artifacts, still acceptable and diagnostic); and 4, not assessable (severe artifacts impairing accurate evaluation). Significant stenosis was defined as a narrowing of the coronary lumen exceeding 50% on the same location in all reconstructed images upon CCTA as well as the need to perform ICA. After CCTA images of all coronary segments were analyzed, the results of CCTA were compared with the results of ICA.

**Comparisons and Evaluations**

Patients were classified into three groups according to mean heart rate: <70 bpm, 70–90 bpm, and >90 bpm; and into another set of three groups according to Agatston calcium score: <100, 100–400, and >400. The
results of the CCTA detection of significant stenoses (lesions >50%) were compared with the results of conventional coronary angiography according on a: (a) per-segment basis, comparing each segment in every vessel; (b) per-vessel basis, looking for the presence of significant lesions of the major coronary vessels; and (c) per-patient basis, looking for the presence of any significant stenotic vessel lesions in each patient (2, 12-17, 23).

**Statistical Analysis**

Statistical analyses were performed using commercially available software (SPSS 12.0, SPSS, Chicago, IL, USA). Quantitative variables were expressed as mean ± SD, and categorical variables were expressed as frequencies or percentages. We divided patients according to heart rate and calcium score and then calculated the diagnostic accuracy on a per-patient, per-segment, and per-vessel basis for each subgroup. Sensitivity, specificity, PPV, and NPV were calculated from Chi-square tests of contingency, and 95% confidence intervals were determined from a binominal expression on a per-patient, per-vessel, and per-segment basis. P-values <0.05 were
considered statistically significant. Inter-observer agreement for the image quality readout and assessment of significant coronary artery stenosis with CCTA was quantified using the kappa value and interpreted as follows: less than 0.20, poor agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, good agreement; and 0.81–1.00, very good agreement.

Results

The mean heart rate was 78.5 ± 16.7 (range 50–126 bpm). The number of patients with heart rates of <70 bpm, 70–90 bpm, and >90 bpm was 34, respectively. Average heart rate during scanning was 60.5 ± 5.6 bpm (range 50–68 bpm) for patients with a heart rate of <70 bpm, 77.5 ± 5.9 bpm (range 70–89 bpm) for patients with a heart rate of 70–90 bpm, and 97.6 ± 8.5 bpm

Fig. 3. A 73-year-old male patient with chest discomfort (mean heart rate during scanning of 106 bpm and an Agatston score of 280.3).
A-C. CTA using DSCT. A curved multiplanar reformation (cMPR) and the coronary tree of the RCA shows diffuse, moderate (>50%) stenosis in the proximal segment due to mixed plaque (arrow). Tracing the axial view of cMPR shows moderate (>50%) stenosis of the coronary artery due to ellipsoidal calcified plaque.
D. ICA in left anterior oblique projection confirms significant stenosis (arrow).
(range 90–126 bpm) for patients with a heart rate of >90 bpm. The mean effective radiation dose, including calcium scoring, was 9.9 ± 1.0 mSv [range 8.9–11.3] for patients with a heart rate of <70 bpm, 10.0 ± 2.3 mSv [range 6.8–12.2] for patients with a heart rate of 70–90 bpm, and 7.9 ± 1.1 mSv [range 7.2–9.8] for patients with a heart rate of >90 bpm. There were no contraindications for nitroglycerin use.

Among the 102 patients, the ramus intermedius was present in only six patients (6 segments). Of the 1,638 segments, the image quality of 1,614 segments (98.5%) was adequate (score 3), but 24 (1.5%) segments were non-assessable. Reasons for the non-assessable image quality include very small vessel diameter below 1.5 mm in seventeen segments (71%), absence in four segments (17%), and a blooming artifact in close proximity to calcifications or motion artifacts in three segments (12%). ICA demonstrated significant CAD in 53 patients (52.0%), insignificant stenosis in 34 (33.3%), and normal coronary artery patency in 15 (14.7%). In comparison with invasive angiography, there were 53 true positive patients (1715 segments) with hemodynamically relevant findings upon CTA. Sixteen patients had single- vessel disease, 19 had two-vessel disease, and 18 had triple-vessel disease. Additionally, there were 2 false-positive patients (15 segments) and 49 true negative patients (1420 segments). There were no false negative patients (8 segments). Accordingly, sensitivity, specificity, PPV, NPV, and accuracy of DSCT for diagnosing coronary artery stenoses on a per-patient basis were 100%, 96%, 98.5%, 93.7%, 98.6%, and 97.8%, respectively.

Overall sensitivity, specificity, PPV, NPV, and diagnostic accuracy of DSCT on a per-segment basis was 95.4%, 96.7%, 89.0%, 98.3%, and 96.1%, respectively. For patients with heart rates of <70 bpm, 70–90 bpm, and >90 bpm, the sensitivity, specificity, PPV, NPV, and accuracy of DSCT on a per-segment basis and a per-vessel basis is shown in Table 1. Diagnostic accuracy was high enough in all three groups such that there were no significant differences between the <70 bpm, 70–90 bpm, and >90 bpm groups (Figs. 1–3) [Tables 2, 3]. If the non-assessable segments were not excluded and regarded as positive, the overall sensitivity, specificity, PPV, NPV, and diagnostic accuracy of DSCT based on a per-segment basis was 88.9%, 98.3%, 95.4%, 96.7%, and 96.1%, respectively.

Calcified vessel wall deposits were present in 70 patients (68.6%). Forty-three of these patients (61.4%) had significant coronary artery stenoses, while 27 (38.6%) had calcifications without significant stenosis. The mean Agatston score was 227.4 ± 420.8 [range 0–2594.5]. The Agatston score was <100 in 63 patients [61.8%, mean score 18.7 ± 25.9], 100–400 in 19 patients (18.6%, mean score 243.5 ± 73.74), and >400 in 20 patients (19.6%, mean score 869.2 ± 596.6). The mean Agatston score for patients with a heart rate of <70 bpm was 210.1 ± 257.0, while patients with a heart rate of 70–90 bpm had a mean Agatston score of 188.0 ± 357.4, and patients with a heart rate of >90 bpm had a mean Agatston score of 284.0 ± 585.7. The mean Agatston score was highest

### Table 2. Diagnostic Accuracy of Dual-source CT Coronary Angiography Per Segment According to Heart Rate

<table>
<thead>
<tr>
<th>Per-Segment</th>
<th>Total</th>
<th>HR &lt; 70</th>
<th>70 ≤ HR ≤ 90</th>
<th>HR &gt; 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity [95%CI]</td>
<td>95.4% [92.4–98.4]</td>
<td>96.0% [91.0–101.0]</td>
<td>95.7% [91.3–100.1]</td>
<td>94.1% [86.5–101.8]</td>
</tr>
<tr>
<td>Specificity [95%CI]</td>
<td>96.7% [95.2–98.2]</td>
<td>95.8% [93.1–98.6]</td>
<td>97.8% [95.8–99.9]</td>
<td>96.4% [93.2–99.5]</td>
</tr>
<tr>
<td>PPV [95%CI]</td>
<td>89.0% [84.4–93.5]</td>
<td>86.3% [78.0–94.6]</td>
<td>92.2% [84.9–99.5]</td>
<td>88.3% [79.0–97.6]</td>
</tr>
<tr>
<td>NPV [95%CI]</td>
<td>98.3% [97.2–99.4]</td>
<td>98.9% [97.7–100.2]</td>
<td>98.5% [96.8–100.1]</td>
<td>97.2% [93.9–100.5]</td>
</tr>
<tr>
<td>Accuracy [95%CI]</td>
<td>96.1% [94.6–97.6]</td>
<td>95.7% [93.2–98.2]</td>
<td>97.1% [94.7–99.5]</td>
<td>95.3% [91.9–98.7]</td>
</tr>
</tbody>
</table>

Note.— HR = heart rate.

### Table 3. Diagnostic Accuracy of Dual-source CT Coronary Angiography Per Vessel According to Heart Rate

<table>
<thead>
<tr>
<th>Per-Vessel</th>
<th>Total</th>
<th>HR &lt; 70</th>
<th>70 ≤ HR ≤ 90</th>
<th>HR &gt; 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity [95%CI]</td>
<td>97.1% [94.5–99.6]</td>
<td>98.5% [96.2–100.7]</td>
<td>99.2% [97.7–100.8]</td>
<td>91.7% [81.6–101.7]</td>
</tr>
<tr>
<td>Specificity [95%CI]</td>
<td>98.5% [97.4–99.6]</td>
<td>98.2% [96.3–100.1]</td>
<td>99.2% [97.7–100.8]</td>
<td>97.9% [95.2–100.5]</td>
</tr>
<tr>
<td>PPV [95%CI]</td>
<td>93.7% [89.3–98.0]</td>
<td>93.6% [86.9–100.2]</td>
<td>97.4% [91.8–102.9]</td>
<td>88.5% [75.2–101.7]</td>
</tr>
<tr>
<td>NPV [95%CI]</td>
<td>98.6% [97.5–99.8]</td>
<td>99.1% [97.7–100.4]</td>
<td>99.5% [98.4–100.6]</td>
<td>96.7% [92.5–100.9]</td>
</tr>
<tr>
<td>Accuracy [95%CI]</td>
<td>97.8% [96.6–98.9]</td>
<td>97.9% [96.3–99.6]</td>
<td>99.0% [97.5–100.5]</td>
<td>95.7% [92.4–98.9]</td>
</tr>
</tbody>
</table>
Discussion

In this study, the degree of accuracy of DSCT for the diagnosis of CAS was high. In addition, we demonstrated that there was no significant difference in the diagnostic accuracy of DSCT among patients with heart rates <70 bpm, 70–90 bpm, or >90 bpm. In the litera-

Table 4. Diagnostic Accuracy of Dual Source CT Coronary Angiography Per Vessel According to Agatston Scores

<table>
<thead>
<tr>
<th>Agatston Score</th>
<th>&lt;100</th>
<th>100–400</th>
<th>&gt;400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>97.2% (92.6–101.8)</td>
<td>98.5% (95.1–101.8)</td>
<td>95.8% (90.7–101.0)</td>
</tr>
<tr>
<td>Specificity</td>
<td>99.0% (97.6–100.5)</td>
<td>99.5% (98.4–100.6)</td>
<td>97.0% (94.3–99.7)</td>
</tr>
<tr>
<td>PPV</td>
<td>97.0% (92.2–101.7)</td>
<td>96.2% (87.8–104.5)</td>
<td>87.4% (76.6–98.1)</td>
</tr>
<tr>
<td>NPV</td>
<td>99.3% (98.2–100.3)</td>
<td>99.4% (98.0–100.8)</td>
<td>97.2% (93.9–100.5)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>98.6% (97.2–100.0)</td>
<td>99.0% (97.6–100.5)</td>
<td>95.6% (92.9–98.3)</td>
</tr>
</tbody>
</table>

Note.— PPV = positive predictive value, NPV = negative predictive value.

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Fig. 4. A 51-year-old male patient with dyspnea (mean heart rate during scanning of 90 bpm and an Agatston Score of 2594.5).
A. Maximum intensity projection image shows diffuse calcification on coronary arteries which cannot detect and grade a stenotic site of coronary artery.
B. cMPR image of the LAD, LCX, and RCA shows diffuse, severe stenosis, due to extensive calcified plaques. Axial tracing of a cMPR image shows severe stenosis of the proximal LAD, due to a horseshoe-shaped calcification [arrow] and diagnosed triple vessel disease.
C. ICA in a left anterior oblique projection confirms significant stenosis in proximal LAD of the same site with Fig. B [arrow] and triple vessel disease, consequently.
ture, although it was very rare, patients who had received a beta-blocker for scanning cardiac CT sometimes experienced low blood pressure, even to a level where it may be considered shock. Also, the use of a beta-blocker was found to be ineffective in lowering the heart rate or contraindicated in up to 20% of patients, despite its utility in decreasing the radiation dose and increasing the diagnostic accuracy (15, 24). However, CCTA using DSCT can be used even in patients with contraindications for beta-blockers, and administration could be avoided in 20% of patients who do not respond to these medications. Based on these results, we suggest that coronary artery imaging using DSCT does not require the administration of beta-blockers to assess CAS when the heart rate is high.

We studied the influence of calcification and heart rate on the diagnostic accuracy of DSCT for CAS, and noted that the calcium score had less of an effect; as long as image quality was not poor secondary to massive coronary artery calcification. It is particularly interesting that the diagnostic accuracy of CAS for patients who had calcium scores >400, decreased mildly compared to patients with calcium scores <400 in this study. Beam-hardening and blooming artifacts have made it difficult to assess the degree of luminal narrowing in CCTA with DSCT, as well as 64-slice MDCT, when heavily calcified plaques are present (8, 10, 12, 25, 26). Based on invasive coronary angiography, diagnostic errors are usually attributable to the overestimation of the degree of stenosis, while the diagnostic accuracy ranged from 67% to 85% (13, 25, 27). Alkadhi et al. (17) showed that, in instances of large and densely calcified plaques, coronary CTA becomes less reliable as a result of blooming artifacts, thereby causing coronary stenosis to be underestimated and an increase in false positives. Brodoefel et al. (18) reported that the diagnostic accuracy of CCTA for stenosis evaluation significantly decreased at a calcium score threshold of >400. This finding is in agreement with previous data [8] from the 64-section CT. On the other hand, Cademartiri et al. (28) reported that no significant impairment of accuracy was found in the presence of a high calcium load. To increase the diagnostic accuracy of CAS for patients with a high heart rate and heavy calcification, the following should be done: firstly, excellent image quality can be obtained through the proper management of patients by instructing them not to move or to hold their breath; secondly, a beta-blocker could be administered on an occasional basis to decrease heart rate; third, technicians should be thoroughly trained in being able to obtain excellent images; fourth, an experienced radiologist should interpret the images; and finally, a variety of imaging analysis methods, such as 1-mm reconstructed axial images, axial images of curved MPR, and curved MPR, especially with the maximum intensity projection-changed algorithms like B40f, should be used. In this study, we noted a high diagnostic accuracy, regardless of high calcium scores, because we used all of the above-mentioned imaging analysis techniques and thus could obtain high-quality images, which increases the diagnostic ability for CAS with heavy calcifications. In particular, the analytical technique of tracing the axial view of cMPR and MIP could be helpful in determining the grades of CAS with high calcium scores.

In contrast to MDCT systems with lower temporal resolution, dual-source technology has demonstrated sufficient clinical robustness, even in the presence of arrhythmias (23) and without the use of negative chronotropic pretreatment in patients with higher heart rates (12–18, 29, 30). In this study, we evaluated arteries, excluding non-diagnostic segments from analysis. Only 1.5% of segments in our study using 64-slice DSCT were classified as non-assessable segments. This is contrary to other 64-slice MDCT studies, which have shown non-diagnostic segments in 3–17% of all segments (6, 7). The results of our study, which included a per-segment analysis showed a very high diagnostic accuracy compared to previous 64-slice CT studies, regardless of heart rate. However, PPV was not high in patients with heart rates >90 bpm [88.3%]. The reason for the decreased PPV was due to the artifact from the elevated heart rate, despite the improved temporal resolution of DSCT. Small distal vessel branches, such as the small distal LAD, were sometimes not adequately visualized and were more sensitive to heart rate in our study. Although the results of this study were excellent - with per-segment sensitivity, specificity, and NPV of 95.4%, 96.7%, and 98.3%, respectively - it is obvious that DSCT still has some limitations in visualizing the small distal branches of coronary arteries when the heart rate is high.

BMI and irregular heartbeats were also found to contribute to relative degradation of image quality (17–19). Raff et al. [8] found a significant deterioration in the accuracy of 64-slice CT in a subgroup of patients with BMI ≥30 kg/m². The recent studies using DSCT were consistent with those of previous 64-slice cardiac CT studies. The projected BMI cut-off for diagnostic image quality
with DSCT was 50 kg/m² [19]. Results of a previous study on 64-slice CT showed heart rate variability as a major determinant of image quality [9]. Likewise, a recent study on DSCT showed that heart rate variability had a persistent impact on global image quality, but this did not translate into a negative effect on accuracy [18].

A limitation of this study was that it was conducted at a single medical center, whereas a multi-center study is required for exact evaluation of diagnostic accuracy of CAS using DSCT in the future. In this study, the patients were enrolled only when they underwent CCTA and ICA simultaneously. That is, the patients who had no accessible coronary artery stenosis did not undergo ICA and were excluded. Hence, a large group study is needed to exclude selection bias in the future.

In conclusion, compared with ICA, CCTA using DSCT has become a reliable method for evaluation of CAS and has demonstrated high diagnostic accuracy and negative predictive value, regardless of heart rate and calcium score. This study demonstrated a high diagnostic accuracy for significant CAS; even in a patient series with a high pre-test probability for CAD as well as a high NPV in patients with higher heart rates and high calcium scores.

Acknowledgements

Thanks to Miles Foltermann of the Harrisco Company for editing assistance.

References

관상동맥 질환의 진단에서 심박수와 석회화 정도에 따른
Dual-source CT의 진단적 정확성

목적: 관상동맥 질환의 진단에서 심박수와 석회화 정도에 따른 64 커널 이중선원CT(dual-source CT, 이하 DSCT)의 진단 정확도를 알아보고자 하였다.

대상과 방법: 관상동맥 질환이 의심되는 환자 중에서 DSCT와 침습적 관상동맥조영술을 모두 시행한 102명(남자 46명, 여자 56명: 평균 연령, 64.1 ± 10.6; 연령 범위, 37-92)의 환자들을 대상으로 하였다. 환자들은 평균 심박수에 따라 70 미만, 70-90, 90 이상의 세 그룹으로 구분되었고 Agatston 점수에 따라 100 미만, 100-400, 400 이상으로 구분되었다. 그리고 각 그룹에 비만도, 평균, 석회화 정도, 음성 예측도, 음성 예측도 그리고 진단적 정확도를 계산하였다.

결과: 혈관별 분석에서 DSCT의 민감도, 특이도, 양성 예측치, 음성 예측치, 진단적 정확도는 심박수 70 미만 환자들에서 98.5%, 98.2%, 93.6%, 99.1%, 97.9%, 심박수 70-90, 90 이상 환자들에서 99.2%, 99.2%, 97.9%, 99.1%, 97.9%, 99.5%, 99%, 심박수 90 이상 환자들에서 91.7%, 97.9%, 88.5%, 96.7%, 95.7%를 보였다. 또한, 석회화 점수가 100 미만 환자들에서 97.2%, 99.0%, 97.0, 99.3%, 98.6%, 100 이상 400 미만 환자들에서 98.5%, 99.5%, 96.2%, 99.4%, 99.0%, 400 이상 환자들에서 95.8%, 97.0%, 87.4%, 97.2%, 95.6%를 보였다. 실험 결과는 심박수와 석회화 정도와 상관없이 관상동맥 질환의 진단에 있어 높은 진단적 정확도와 음성 예측도를 보였다.