Ultra-High-Resolution Computed Tomography Angiography for Assessment of Coronary Artery Stenosis

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Background: Limitations of coronary computed tomography (CTA) include false-positive stenosis at calcified lesions and assessment of in-stent patency. A prototype of ultra-high resolution computed tomography (U-HRCT: 1,792 channels and 0.25-mm slice thickness×128 rows) with improved spatial resolution was developed. We assessed the diagnostic accuracy of coronary artery stenosis using U-HRCT.

Methods and Results: Seventy-nine consecutive patients who underwent CTA using U-HRCT were prospectively included. Coronary artery stenosis was graded from 0 (no plaque) to 5 (occlusion). Stenosis grading at 102 calcified lesions was compared between U-HRCT and conventional-resolution CT (CRCT: 896 channels and 0.5-mm slice thickness×320 rows). Median stenosis grading at calcified plaque was significantly improved on U-HRCT compared with CRCT (1; IQR, 1–2 vs. 2; IQR, 1–3, $P<0.0001$). Assessability of in-stent lumen was evaluated on U-HRCT in 79 stents. Stent strut thickness and luminal diameter were quantitatively compared between U-HRCT and CRCT. Of 79 stents, 83.5% were assessable on U-HRCT; 80% of stents with diameter 2.5 mm were regarded as assessable. On U-HRCT, stent struts were significantly thinner (median, 0.78 mm; IQR, 0.7–0.83 mm vs. 0.83 mm; IQR, 0.75–0.92 mm, $P=0.0036$), and in-stent lumens were significantly larger (median, 2.08 mm; IQR, 1.55–2.51 mm vs. 1.74 mm; IQR, 1.31–2.06 mm, $P<0.0001$) than on CRCT.

Conclusions: U-HRCT with improved spatial resolution visualized calcified lesions with fewer artifacts. The in-stent lumen of stents with diameter ≥ 2.5 mm was assessable on U-HRCT.

Key Words: Calcified plaque; Coronary artery disease; Coronary computed tomography angiography; Spatial resolution; Stent

Coronary computed tomography angiography (CTA) is an established modality to assess coronary artery disease (CAD). Its diagnostic accuracy, especially negative predictive value (NPV), to detect obstructive stenosis is high,^{1,2} and CTA has been especially useful in intermediate-risk patients by performing a gatekeeper function with regard to invasive coronary angiography (ICA).³ In contrast, a low positive predictive value (PPV) is one of the limitations of CTA. In patients with false-positive CTA, an additional test such as stress echocardiography or stress single-photon emission computed tomography (SPECT) becomes necessary. Factors underlying false positives on CTA include motion artifact because of limitations of temporal resolution, and calcified lesions because of limitations of spatial resolution. Assessment of stented lesions is another limitation of CTA. The

quantification of in-stent lumen on coronary CTA has been challenging due to beam-hardening artifacts caused by metallic stent struts, especially in stents with diameter <3.0 mm, with this being attributable mainly to the limited spatial resolution of conventional-resolution CT (CRCT).⁴ A prototype of the ultra-high-resolution CT (U-HRCT) scanner (1,792 channels, 0.25-mm slice thickness×128 rows, 0.20-mm spatial resolution for helical scan) was used at Fujita Health University between May 2015 and November 2015. This CT scanner obtained pharmaceutical approval and could be used for daily clinical practice. We assessed the diagnostic accuracy of coronary artery stenosis on U-HRCT and compared the image quality at calcified lesions and stented lesions between U-HRCT and CRCT to determine whether high spatial resolution contributed to improvement of diagnostic accuracy in practice.

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Methods

Subjects

Between May 2015 and November 2015, patients undergoing CTA for suspected or known CAD, who had heart rate (HR) <65 beats/min and body mass index <30 kg/m², and who were therefore eligible for U-HRCT, were prospectively enrolled in this study. Informed consent was obtained at the time that the patient decided to undergo CTA, and selection of CT scanner was explained as follows: "If you agree to take part in this study, you may not be included in this study if your HR immediately before CT is >65 beats/min. You will then undergo CT examination with conventional-resolution CT scanner." HR was evaluated immediately before entering the CT exam room, and patients with HR ≥65 beats/min underwent CTA using 320-slice CT, not U-HRCT, and these patients were excluded from this study. In patients with HR <65 beats/min immediately before entering the exam room, if HR was >65 beats/min immediately before contrast-enhanced CT, landiolol was injected, and CT was performed using U-HRCT. Exclusion criteria were as follows: chronic kidney disease (serum creatinine >1.5 mg/dL or glomerular filtration rate <45 mL/min/1.73 m²), allergy to contrast media, atrial fibrillation, and inability to perform breath holds. Forty-six patients underwent U-HRCT for acute coronary syndrome (ACS) and 33 patients, for stable angina pectoris (SAP). CTA was performed to evaluate coronary artery stenosis in 29 ACS patients including unstable angina pectoris or non-ST elevation myocardial infarction (MI); patients with ST-elevation MI or who required emergency ICA were not included in this study. The remaining 17 patients with ACS underwent CT for plaque assessment of non-culprit lesion. In patients with

suspected SAP, 32 had chest symptoms, and one patient without chest symptoms underwent CT because of electrocardiogram (ECG) abnormality at preoperative check. Twenty-three patients who underwent CTA on CRCT before U-HRCT were evaluated for stenosis grading at calcified lesions. Forty-six patients had a history of percutaneous coronary intervention with stent implantation before U-HRCT. Of 87 stents in 46 patients, 79 were included in the stent analysis; 8 overlapping stents were excluded. Of the 46 patients with stented lesions, 13 who also underwent CRCT, had comparison of the image quality between U-HRCT and CRCT. In 689 segments from 59 patients with ICA, luminal stenosis was compared between U-HRCT and ICA. Stenosis grading at calcified plaque was compared in 24 lesions from 9 patients between U-HRCT, CRCT, and ICA. Data on medical history and categorical risk factor status were obtained. The institutional ethics committee at Fujita Health University approved the study (HM15-200), and written informed consent was obtained from the participants.

U-HRCT and CRCT Specifications

The U-HRCT scanner was a 128-row detector CT scanner (TSX-304R; Toshiba Medical Systems, Otawara, Japan). The detector matrix of the U-HRCT is 1,792 channels×128 rows, and the size of each element is 0.25 mm×0.25 mm at the isocenter; spatial resolution of the Z-axis is 0.2 mm. The beam collimation is 0.25 mm×128, 32 mm at the isocenter. The fastest rotation time of the U-HRCT is 350 ms. The size of the small focal spot of the X-ray tube is 0.6×0.6 mm and the maximum output at small focus is 120 kV and 290 mA, or 135 kV and 260 mA. The maximum scanning field of view (SFOV) is 500 mm, and the maximum scanning time is 100 s. The bore size is 78 cm. The U-HRCT

matrix number was 1,024, and the pixel value was 0.18 mm.

The CRCT was a 320-row area detector CT (Aquilion ONE; Toshiba Medical Systems, Otawara, Japan). The detector matrix of the CRCT is 896 channels $\times$ 320 rows, and the size of each element is 0.5 mm $\times$ 0.5 mm at the isocenter. The beam collimation is 0.5 mm $\times$ 320, 160 mm at the isocenter. The fastest rotation time of the CRCT is 275 ms. The size of the small focal spot of the X-ray tube is 0.9 $\times$ 0.8 mm and the maximum output at the small focus is 120 kV and 350 mA, or 135 kV and 310 mA. The maximum SFOV is 500 mm, and the maximum scanning time is 100 s. The bore size is 78 cm. The CRCT matrix number was 512, and pixel value was 0.35 mm. Appearance and geometry of the channel direction of the U-HRCT scanner are shown in **Figure 1**.

U-HRCT and CRCT Protocols

Before imaging, in patients without contraindications, oral metoprolol and/or i.v. landiolol was given if HR was >65 beats/min. Nitroglycerin was used in all patients before scanning. For contrast-enhanced CT, 390 mgI/kg contrast medium was injected in 17 s, followed by saline 30 mL at 3.0 mL/s for U-HRCT; and 245 mgI/kg contrast medium was injected in 12 s followed by saline 20 mL at 3.0 mL/s for CRCT. On U-HRCT, axial scan was performed with a prospective gated scan for segment reconstruction. On CRCT, axial scan was performed with prospective gated scan in 1 heart beat at HR <65 beats/min for half reconstruction, and in 2 or 3 heart beats at HR $\geq$ 65 beats/min for segment reconstruction. The raw CT data were reconstructed using algorithms optimized for prospective ECG-gated segment reconstruction. The reconstructed CT data were transferred to a computer workstation (SURE Plaque™, Toshiba Medical Systems, Otawara, Japan) for post-processing. Cross-sectional multi-planar reconstruction images and curved-planar reconstruction images on U-HRCT and CRCT were reconstructed to assess the coronary arteries on a 4K monitor.

Stenosis Grading on CT

Coronary arteries were divided into 15 segments based on the American Heart Association classification, and the stenosis grade was evaluated in coronary arteries with

diameter $\geq$ 1.5 mm. Stenosis was visually graded from 0 to 5: 0, absence of plaque and no luminal stenosis; 1, <25% stenosis; 2, 25–49% stenosis; 3, 50–69% stenosis; 4, 70–99% stenosis; and 5, occluded.⁵ Significant stenosis was defined as stenosis $\geq$ 70%.

Calcified Lesions

All coronary plaques were classified as calcified, partially calcified, or as non-calcified.⁶ In patients who underwent CRCT before U-HRCT, stenosis grading at calcified lesions was compared.

In-Stent Lumen Assessability

Stented lesions were classified into assessable and unassessable. Stents were regarded as assessable if artifacts such as partial volume effects by stent struts, beam hardening, motion artifacts, calcification, or low contrast/noise ratio were not present, and the lumen within the stent was clearly visible. Stents with minor beam hardening artifacts directly adjacent to the stent struts that did not obscure the vessel lumen were regarded as assessable. Contrast attenuation inside and at both edges of the stents compared with the vessel lumen was regarded as neointimal proliferation.⁷ Representative cases of assessable and unassessable stents are given in **Figure 2**. Neointimal proliferation with >50% narrowing of in-stent lumen was regarded as in-stent restenosis (ISR). Unassessable stents were also regarded as ISR for comparison with ICA. Two experienced cardiologists who were unaware of the patient's clinical information, stent type, and stent size interpreted the CT images by consensus by visual estimation. Any disagreement was resolved by a third independent observer.

Quantitative Stent Analysis

In patients who underwent CRCT before U-HRCT, the automated lumen visibility measurements were performed with a custom-build tool to compare the image quality of the same stents between CRCT and U-HRCT.⁷ This tool constructs the average attenuation profile through the stent in the axial plane. The calculation of the average attenuation profile in the axial plane was done as follows. First, the stent proximal and distal edges on the stretched MPR image were determined, with the first, second, and

Figure 3. Quantitative analysis of stents. (**Upper**) After determination of the center of the stent on (**A**) cross-sectional image, (**B**) attenuation profiles were calculated at 15° intervals around the center. (**C**) Attenuation profiles were averaged, and full width at half maximum of lumen (FWHM-Lumen) and full width at half maximum of strut (FWHM-Stent) were measured. (**Lower**) FWHM-Lumen on ultra-high-resolution computed tomography (U-HRCT) was significantly larger than on conventional-resolution computed tomography (CRCT). FWHM-Stent was significantly thinner on U-HRCT than on CRCT.

third quartile points determined as the calculated points. If there was any calcification at the calculated point, it was slid outward to the point without calcification. Second, after determination of the center of the stent on the cross-sectional image by the user (**Figure 3A**), attenuation profiles were calculated at 15° intervals around the center (**Figure 3B**), and the full width at half maximum of lumen (FWHM-Lumen) and full width at half maximum of strut (FWHM-Stent) were measured. And third, the average FWHM-Lumen and FWHM-Stent were calculated at each calculated slice (**Figure 3C**).

ICA and Luminal Stenosis

ICA using the standard method was performed according to the attending physician's decision. Quantitative coronary angiography was performed, and percent diameter stenosis (%DS), which was calculated using CMS (MEDIS, Leiden, the Netherlands), was defined as reduction of minimum lumen diameter compared with the vessel diameter estimated with proximal and distal reference. All stented segments (including the 5 mm proximal and distal to stent edges) were evaluated by two experienced cardiologists who were blinded to the CT findings. Significant stenosis was defined as stenosis $\geq 75\%$. Binary ISR was defined as %DS $> 50\%$ in the stented segment on ICA.

Statistical Analysis

JMP version 11.0 (SAS Institute, Cary, NC, USA) was used for all statistical analyses. Two-sided $P < 0.05$ was considered statistically significant. Shapiro-Wilk test was used to assess the normality of continuous data. Continuous measurements are expressed as mean $\pm$ SD for normally distributed variables or median (IQR; 25th–75th percentile) for non-parametric data, and compared using Student's t-test or Mann-Whitney U-test. Categorical variables are presented as frequency (percentage) and were compared using chi-squared test or Fisher exact test depending on the data. Wilcoxon signed-rank test was used for comparison of paired variables. Diagnostic accuracy of U-HRCT to detect stenosis is presented as sensitivity, specificity, PPV, and NPV. Diagnostic accuracy to detect stenosis $\geq 50\%$ on ICA at calcified plaque was compared between U-HRCT and CRCT using receiver operating characteristics (ROC) curve analysis.

Results

Patient Characteristics

Patient characteristics are listed in **Table 1**. R-R interval at scanning was $1,043 \pm 130$ ms. Average radiation exposure was 7.4 ± 3.6 mSv; radiation exposure with scanning at diastole was 6.2 ± 1.9 mSv. Median coronary artery calcium

Table 1. Patient Characteristics		
Characteristics	n=79	
Age (years)	66.7±11.8	
Male	56 (70.9)	
Hypertension	41 (51.9)	
Dyslipidemia	31 (39.2)	
Diabetes	22 (27.8)	
BMI (kg/m ²)	22.9±3.3	
Current and past smoking	50 (62.3)	
R-R interval (ms)	1,043±130	
Radiation exposure (mSv)	7.4±3.6	
At diastole	6.2±1.9	
CACS	152 (32–417)	

Data given as mean±SD, n (%) or median (IQR). BMI, body mass index; CACS, coronary artery calcium score.

score (CACS) was 152 (IQR, 32–417).

Luminal Stenosis

Of 79 patients, 59 underwent ICA ≤3 months before or after U-HRCT. Median interval between U-HRCT and ICA was 3 days (IQR, 1–12 days). Median CACS in 59 patients on U-HRCT was 171 (IQR, 49–503); 17 patients (29%) had CACS >400. After exclusion of 66 stented segments, luminal stenosis in 689 segments was evaluated on U-HRCT and on ICA. Significant stenoses were detected in 122/689 segments (17.7%) in 47 patients (79.7%) on U-HRCT, and in 97 segments (14.1%) in 44 patients (74.6%) on ICA. On patient-based analysis, the diagnostic accuracy of U-HRCT to detect severe stenosis on ICA had sensitivity 100%, specificity 80.0%, PPV 93.6%, and NPV 100%, respectively. On segment-based analysis, the diagnostic accuracy had sensitivity 100%, specificity 95.8%, PPV 79.5%, and NPV 100%, respectively. The 25 false-positive segments on U-HRCT included 8 calcified, 13 partially calcified, and 4 non-calcified plaques.

Stenosis Grading at Calcified Lesions

In 23 patients who underwent CRCT before U-HRCT, stenosis grading at calcified plaque was compared. Median interval between CRCT and U-HRCT was 357 days (IQR, 61–368 days). R-R interval at CRCT was 1,017±200 ms. Median CRCT radiation exposure was 2.9 mSv (IQR, 1.9–7.9 mSv); radiation exposure on CRCT at diastole was

Figure 4. Stenosis grading at calcified plaque was significantly improved on ultra-high-resolution computed tomography (U-HRCT) compared with conventional-resolution computed tomography (CRCT).

2.4 mSv (IQR, 1.7–3.3 mSv). In 19 of the 23 patients, 102 lesions had calcification. Lesions with ≥50% stenosis were detected in 27 lesions on CRCT, but 23 of 27 lesions were classified as <50% stenosis on U-HRCT. Stenosis grading was significantly improved on U-HRCT compared with CRCT (median, 1; IQR, 1–2 vs. 2; IQR, 1–3, P<0.0001; **Figures 4,5**). Interobserver reproducibility was good with κ=0.88 for U-HRCT and κ=0.83 for CRCT. Stenosis grading was compared in 24 calcified lesions from 9 patients between U-HRCT, CRCT, and ICA. On ICA, only one lesion had ≥50% stenosis at calcified lesion. On CTCR, 10 lesions had ≥50% stenosis. Of the 10 lesions with ≥50% stenosis on CRCT, 2 lesions were regarded as ≥50% stenosis on U-HRCT; 8 calcified lesions had <50% stenosis on U-HRCT. On ROC curve analysis, the diagnostic accuracy of U-HRCT to detect stenosis ≥50% was improved compared with CRCT by ICA at calcified plaques (area under the curve, 0.98 vs. 0.80).

Figure 5. Calcified plaques on (A) ultra-high-resolution computed tomography (U-HRCT) were smaller and had fewer artifacts than on (B) conventional-resolution computed tomography (CRCT).

Figure 6. Proportion of assessable stents on ultra-high-resolution computed tomography.

Table 2. Stent Characteristics

	Total stents (n=79)	Assessable stents (n=66)	Unassessable stents (n=13)	P-value
Stent diameter (mm)		3.0 (2.5–3.5)	2.5 (2.25–2.75)	0.0002
2.25	8 (10.1)	2	6	
2.5	20 (25.3)	16	4	
2.75	5 (6.3)	5	0	
3.0	18 (22.8)	16	2	
3.25	1 (1.3)	1	0	
3.5	21 (26.6)	20	1	
4.0	6 (7.6)	6	0	
Stent length (mm)	19.7±7.1	18 (15–24)	23 (14.5–35)	0.24
Stent strut thickness (μm)	81 (81–125)	81 (81–100.5)	81 (81–125)	0.22
Post-balloon diameter (mm)	3.1±0.6	3.25 (2.75–3.5)	2.5 (2.25–3)	0.0001
Post-balloon pressure (atm)	16.7±10.8	16 (12–18)	14 (12–18)	0.59
Stent lesion				0.76
RCA	24 (30.4)	19 (28.8)	5 (38.5)	
LMT	3 (3.8)	3 (4.5)	0 (0)	
LAD	42 (53.2)	36 (54.6)	6 (46.2)	
LCX	10 (12.7)	8 (12.1)	2 (15.4)	

Data given as mean±SD, n (%) or median (IQR). BMS, bare metal stent; DES, drug-eluting stent; LAD, left anterior descending; LCX, left circumflex; LMT, left main trunk; RCA, right coronary artery.

Assessability of Stented Segments

In-stent patency on U-HRCT was compared with ICA in 66 stents from 33 patients. ISR was detected in 3 stents on ICA. On U-HRCT, 50 lesions were identified as patent, 5 lesions had suspected ISR, and 11 lesions were not assessable. All 3 ISR lesions on ICA were detected on U-HRCT. On U-HRCT, assessability of stented lesions was evaluated in 79 stents from 46 patients. Eleven patients had unassessable stents. Although there were no significant differences in any baseline patient characteristics between patients with and without unassessable stents, average R-R interval was longer in patients without unassessable stents (1,128±114 vs. 1,001±127 ms). Sixty-six stents (83.5%) were assessable. Although 25% of stents with diameter 2.25 mm

(2/8 stents) were assessable, 90.1% of stents with diameter ≥2.5 mm were regarded as assessable: 80% (16/20) of 2.5-mm diameter stents, 100% (5/5) of 2.75-mm diameter stents, 88.9% (16/18) of 3.0-mm diameter stents, 100% (1/1) of the 3.25-mm diameter stent, 95.2% (20/21) of the 3.5-mm diameter stents, and 100% (6/6) of the 4.0-mm diameter stents (**Figure 6**). Interobserver reproducibility was good, with $\kappa=0.80$. Median stent diameter (3.0 mm; IQR, 2.5–3.5 mm vs. 2.5 mm; IQR, 2.25–2.75 mm; $P=0.0002$) and median balloon diameter for post-stent dilatation (3.25 mm; IQR, 2.75–3.5 mm vs. 2.5 mm; IQR, 2.25–3.0 mm; $P=0.0001$) were significantly larger in assessable stents than in unassessable stents (**Table 2**). There were no significant differences in stent length, stent strut thickness, or stented region

between assessable and unassessable stents.

Stented Lesions: U-HRCT vs. CRCT

In 17 stents from 13 patients who underwent CRCT before U-HRCT, assessability of stents was compared between U-HRCT and CRCT. Average interval between CRCT and U-HRCT was 301 ± 133 days. Although average R-R interval was not significantly different between U-HRCT and CRCT ($1,147.9 \pm 118.9$ vs. $1,106.2 \pm 165.3$ ms, $P=0.24$), radiation exposure was significantly lower for CRCT (7.2 ± 2.7 vs. 2.5 ± 1.2 mSv, $P=0.0002$). On CRCT, assessability of stents was 0% (0/1) of the 2.25-mm stents, 25% (1/4) of the 2.5-mm stents, and 100% (1/1) of the 2.75-mm stent. Of 11 stents with diameter ≥ 3 mm, 82% were assessable: 75% (3/4) of the 3-mm stents, 100% (3/3) of the 3.5-mm stents, and 75% (3/4) of the 4-mm stents. On U-HRCT, 1 stent with diameter 2.5 mm was unassessable, and the remaining 16 stents were assessable (5 stents that were unassessable on CRCT could be assessed on U-HRCT).

On quantitative analysis, 51 axial slices of 17 stents were evaluated. One axial slice on U-HRCT and 6 axial slices on CRCT were uninterpretable because of the image quality, which was too poor for quantitative assessment. The median lumen diameter of 17 stents was 3.0 mm (IQR, 2.5–3.75 mm). The median FWHM-Lumen calculated on U-HRCT was significantly larger than on CRCT (2.08 mm; IQR, 1.55–2.51 mm vs. 1.74 mm; IQR, 1.31–2.06 mm, $P<0.0001$; **Figure 3 Lower**). The FWHM-Stent on U-HRCT was significantly smaller than on CRCT (median, 0.78 mm; IQR, 0.70–0.83 mm vs. 0.83 mm; IQR, 0.75–0.92 mm, $P=0.0036$).

Discussion

This is the first study to evaluate coronary artery stenosis in vivo using a prototype of U-HRCT with slice thickness 0.25 mm. Novel findings in this study were: (1) given that calcified plaques was visualized with fewer artifacts, stenosis grading at calcified lesions could be assessed more precisely on U-HRCT than CRCT; and (2) in-stent patency of 2.5-mm stents could be evaluated on U-HRCT.

Calcified Lesions

CTA can diagnose CAD with high sensitivity and NPV, although it has the limitation of low PPV.^{1,2} Spatial resolution limitations are associated with streak and beam hardening artifacts of calcification, and these artifacts could be related to the occurrence of false positives for significant stenosis. The Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography (ACCURACY) study using 64-slice CT reported that specificity was reduced in patients with CACS >400 .¹ The Coronary Artery Evaluation Using 64-Row Multidetector Computed Tomography Angiography (Core 64) study excluded patients with CACS >600 .² In patients with suspected severe stenosis at calcified lesions on CRCT, an additional test such as stress myocardial perfusion imaging using SPECT⁸ or CT^{9,10} was needed to evaluate ischemia at calcified lesions. To overcome this limitation, an approach using subtraction CTA has been reported; image quality at calcified plaques on subtraction showed improvement as compared with conventional CTA.^{11,12} The diagnostic accuracy of subtraction CTA, however, is not perfect, and it has the disadvantages of requiring long breath-hold times, and long image processing

times, and greater radiation exposure, and misregistration artifacts.¹³

The CRCT used in this study was a 320-row area detector CT with gantry rotation time 275 ms. Area detectors with wide coverage have improved image quality compared with 64-slice CT with similar spatial resolution.¹⁴ The present U-HRCT prototype had limitations associated with temporal resolution and detector coverage, with banding and motion artifacts possibly affecting image quality. Nonetheless, calcified plaques were visualized with fewer artifacts on U-HRCT compared with CRCT, and the number of calcified lesions with false-positive severe stenosis was lower on U-HRCT.

Stented Lesions

Although coronary CTA is not feasible for the evaluation of stents with diameter <3.0 mm,^{4,15} in the current study the in-stent lumen of stents with diameter ≥ 2.5 mm could be assessed on U-HRCT. Sheth et al reported that consistently assessable stents were ≥ 3 mm (85%), whereas those <3 mm were mostly unassessable (26%) on 64-slice CT.⁴ Direct visualization of the in-stent lumen on coronary CTA was challenging, mainly because of beam hardening and partial volume effects.^{16,17} With regard to ISR, a favorable effect of improved spatial and temporal resolution on image quality has been suggested.^{18–20} In previous reports on 64-slice CT using conventional spatial resolution, slice thickness was 0.5–0.6 mm. Gantry rotation time varied in the range of 330–400 ms, and the effective radiation dose was around 6–20 mSv.² Compared with the previous reports on CRCT, the present CRCT involved improved spatial resolution. In contrast, the gantry rotation time was similar to that in previous reports. CRCT in this study had a faster gantry rotation time than U-HRCT and wider detector coverage, which made it possible to obtain a whole heart image in a single heart beat. In the present study, 90.1% of stents with diameter >2.5 mm were assessable. This indicates that the partial volume effect and beam hardening artifacts were decreased because of improved spatial resolution. Even with a slower gantry rotation time and smaller coverage of the detector, U-HRCT still had improved image quality of the stented lesions. This was attributed to the lower number of artifacts induced by U-HRCT. The quantitative assessment indicated better visualization of the stent lumen on U-HRCT, supporting this contention.

Limitations of the U-HRCT Prototype

U-HRCT has improved spatial resolution, and hence improved diagnostic accuracy to detect significant stenosis and in-stent patency. It is useful for clinical daily practice, although its diagnostic accuracy is not perfect compared with ICA. In contrast, radiation exposure for U-HRCT was significantly higher than that for CRCT in the present study, the radiation exposure at diastole was similar to that in previous reports on 64-slice CT. Due to the limitation of the gantry rotation time, patients with HR >65 beats/min and patients with atrial fibrillation were excluded from this study. Another limitation of U-HRCT was the amount of contrast media needed. Given that the width of the U-HRCT detector was the same as the 64-slice CT with 0.5-mm slice thickness, a longer helical scan time was needed for coronary CTA with U-HRCT than for 320-slice CT. This is why more contrast media was needed than for CRCT with 320-slice CT, which needed only 1 heart beat

to obtain a whole heart image. It is obvious that whole heart coverage by the area detector with a faster rotation speed contributed to the improvement in the temporal resolution, and decreased radiation exposure and contrast media. Therefore, improvement of spatial resolution on area detector CT is expected in the future.

Study Limitations

First, this study involved a small number of patients, because this prototype CT scanner was installed for only 6 months. Second, for stented lesion evaluation, ISR on ICA was seen in a few cases, precluding any precise determination of the feasibility of U-HRCT to assess ISR. Coronary CTA, however, has a high NPV for detecting ISR when the in-stent lumen is clearly visualized. Therefore, it is anticipated that U-HRCT will be able to decrease the number of additional examinations needed after coronary CTA to exclude ISR.

Conclusions

U-HRCT with improved spatial resolution was able to visualize calcified lesions with fewer artifacts, and to visualize the in-stent lumen of stents with diameter ≥ 2.5 mm. Owing to its improved spatial resolution, U-HRCT might overcome the previous limitations of CRCT.

Disclosures

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