Prospective Validation of Standardized, 3-Dimensional, Quantitative Coronary Computed Tomographic Plaque Measurements Using Radiofrequency Backscatter Intravascular Ultrasound as Reference Standard in Intermediate Coronary Arterial Lesions

Results From the ATLANTA (Assessment of Tissue Characteristics, Lesion Morphology, and Hemodynamics by Angiography With Fractional Flow Reserve, Intravascular Ultrasound and Virtual Histology, and Noninvasive Computed Tomography in Atherosclerotic Plaques) I Study

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Objectives This study sought to determine the accuracy of 3-dimensional, quantitative measurements of coronary plaque by computed tomography angiography (CTA) against intravascular ultrasound with radiofrequency backscatter analysis (IVUS/VH).

Background Quantitative, 3-dimensional coronary CTA plaque measurements have not been validated against IVUS/VH.

Methods Sixty patients in a prospective study underwent coronary X-ray angiography, IVUS/VH, and coronary CTA. Plaque geometry and composition was quantified after spatial coregistration on segmental and slice-by-slice bases. Correlation, mean difference, and limits of agreement were determined.

Results There was significant correlation for all pre-specified parameters by segmental and slice-by-slice analyses (r = 0.41 to 0.84; all p < 0.001). On a segmental basis, CTA underestimated minimal lumen diameter by 21% and overestimated diameter stenosis by 39%. Minimal lumen area was overestimated on CTA by 27% but area stenosis was only underestimated by 5%. Mean difference in noncalcified plaque volume and percent and calcified plaque volume and percent were 38%, 22%, 104%, and 64%. On a slice-by-slice basis, lumen, vessel, noncalcified-, and calcified-plaque areas were overestimated on CTA by 22%, 19%, 44%, and 88%. There was significant correlation for percentage of atheroma volume (0.52 vs. 0.54; r = 0.51; p < 0.001). Compositional analysis suggested that high-density noncalcified plaque on CTA best correlated with fibrous tissue and low-density noncalcified plaque correlated with necrotic core plus fibrofatty tissue by IVUS/VH.

Conclusions This is the first validation that standardized, 3-dimensional, quantitative measurements of coronary plaque correlate with IVUS/VH. Mean differences are small, whereas limits of agreement are wide. Low-density noncalcified plaque correlates with necrotic core plus fibrofatty tissue on IVUS/VH. (J Am Coll Cardiol Intv 2011;4:198–208) © 2011 by the American College of Cardiology Foundation
Atherogenic lipoprotein particle deposition and the ensuing inflammation in the arterial wall result in geometric and compositional changes that can be detected by imaging modalities (1). Traditionally, intravascular ultrasound (IVUS) has been used for precise measurements of plaque geometric parameters (2,3) and several tissue characterization approaches have also been introduced based on IVUS, such as radiofrequency backscatter (intravascular ultrasound with radio frequency backscatter analysis [IVUS/VH]) (4), elastography, and palpography (5). Both grayscale IVUS-based geometric measurements and IVUS/VH-based compositional measurements have been shown to predict clinical outcomes (6,7).

Contrast-enhanced coronary computed tomography angiography (CTA) has been introduced for stenosis detection (8) and CTA has also been proposed as an emerging tool for the detection, characterization, and quantification of coronary atherosclerotic plaques (9-12). Although a few studies have evaluated the accuracy of CTA for the measurement of geometric and compositional plaque parameters, precise quantitative plaque measurements by CTA have not been validated against IVUS/VH. We recently developed a standardized, reproducible, 3-dimensional, quantitative method for the quantification of geometric and compositional coronary plaque parameters (12). Whether quantitative CTA-derived measurements are precise enough on a per-patient level and on a population level is important, as such precision will determine whether CTA-derived quantitative measurements can be used in clinical practice in individual patients and in populations, for clinical research purposes.

The primary objective of the present study was to evaluate the accuracy of these standardized, 3-dimensional measurements on a segmental basis, using IVUS/VH as reference standard. The secondary objective was to determine the accuracy of CTA measurements on a slice-by-slice basis against IVUS/VH. The tertiary objective was to determine plaque components by IVUS/VH that correspond to high-density and low-density noncalcified plaque (HD-NCP and LD-NCP) on CTA. We hypothesized that CTA-derived measurements significantly correlate with IVUS/VH measurements.

### Methods

#### General study design.

The ATLANTA (Assessment of Tissue Characteristics, Lesion Morphology, and Hemodynamics by Angiography With Fractional Flow Reserve, Intravascular Ultrasound and Virtual Histology, and Noninvasive Computed Tomography in Atherosclerotic Plaques) study was a prospective, single-center, investigator-initiated study approved by the Institutional Review Board of Piedmont Healthcare. The general study design is shown in Figure 1. Here we report the results of phase I, which included a multimodality approach to intermediate coronary lesions in patients without previous coronary artery disease who presented with signs or symptoms suggestive of myocardial ischemia. Patients with intermediate coronary arterial lesions were included from either the cardiac catheterization laboratory or the CT laboratory. All patients underwent invasive X-ray coronary angiography (XRA) with quantitative coronary angiography (QCA), fractional flow reserve measurements, IVUS/VH, and multislice CTA. We evaluated and cross-validated luminal stenosis, plaque geometry, plaque composition, and hemodynamic measurements among all involved modalities.

**Invasive X-ray coronary angiography.** Invasive X-ray coronary angiography was performed by the Judkins technique based on standard institutional protocols, with a minimum of 5 views of the left and 2 views of the right coronary systems. Once the study lesion was identified, we performed at least 2 orthogonal views for QCA purposes.

**CT coronary angiography image acquisition.** All image acquisition was performed on a $32 \times 2$ CT system (Somatom 64, Siemens, Erlangen, Germany) using our institutional imaging protocols as published (13). Contrast-enhanced coronary artery CTA was performed during end–expiratory breath-hold using retrospective electrocardiographic-gating. Oral and intravenous metoprolol was administered as needed to keep the heart rate below 60 beats/min. After noncontrast localization image acquisition, a test bolus of 20 ml iodinated contrast (Visipaque, GE Amersham Health, Sunnyvale, California) was administered at a rate of 3 to 5 ml/s to determine the delay until the arrival of the contrast in the ascending aorta for optimal opacification of the coronary arteries. Coronary arterial image acquisition was performed using 60 to 80 ml of intravenous contrast followed by 30 ml of normal saline flush. Acquisition parameters included $32 \times 2$ detector rows, 0.6-mm collimation, gantry rotation 330 ms, pitch 0.24, tube voltage 120 kV, and tube current 800 to 950 mA. Images were reconstructed in 0.6-mm axial slices using 3 different reconstruction algorithms in 10 phases of the cardiac cycle.

### Abbreviations and Acronyms

- %AS = percentage of area stenosis
- %DS = percentage of diameter stenosis
- CAP = calcified atherosclerotic plaque
- CTA = computed tomography angiography
- FI = fibrous
- FF = fibrofatty
- HD-NCP = high-density noncalcified plaque
- IVUS = intravascular ultrasound
- IVUS/VH = intravascular ultrasound with radiofrequency backscatter analysis
- LD-NCP = low-density noncalcified plaque
- MLD = minimal lumen diameter
- MLA = minimal lumen area
- NC = necrotic core
- NCP = noncalcified plaque
- PAV = percentage of atheroma volume
- QCA = quantitative coronary angiography
- XRA = invasive X-ray coronary angiography

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IVUS/VH image acquisition. After intracoronary injection of nitroglycerin (mean total dose per case: 561.5 μg; range 0 to 1,800 μg) and after placing a guiding catheter in the target coronary artery, a 3.2-F, 20-mHz ultrasound catheter (Eagle Eye, Volcano Inc., Rancho Cordova, California) was inserted and was advanced at least 2 cm beyond the most distal portion of the target lesion. Automated pullback was performed at a rate of 0.5 mm/s (R-100, Volcano Inc.). The electrocardiographic signal was simultaneously recorded for the reconstruction of the radiofrequency backscatter information using In-Vision gold (Volcano Inc.).

Anatomical image coregistration and image analysis. One pre-specified study lesion was identified in each patient. An anatomical segment containing the entirety of the study lesion was then selected, which could be easily identified based on standard anatomical landmarks on all 3 modalities (XRA, CTA, and IVUS/VH) using septal, diagonal, obtuse marginal, and right ventricular marginal branches (Fig. 2). Once the study segment was identified, it was independently analyzed on all 3 modalities.

QCA. Deidentified angiographic datasets were transferred to a free-standing workstation (Encompass, version 2.0, B17,
HeartLab, Westerly, Rhode Island) and were presented to an interventional cardiologist (A.K.) with 16 years of experience in random order. The study lesion and study segment were identified in multiple projections and lesion borders were contoured manually. Minimal lumen diameter and reference diameter were measured and percentage of diameter stenosis (%DS) was calculated.

**CTA IMAGE ANALYSIS.** Deidentified datasets were transferred to a dedicated workstation (Vitrea 2.0, Vital Images, Minnetonka, Minnesota) and were analyzed by an experienced, level III trained cardiologist (S.R.), using our previously described, standardized, and reproducible 3-dimensional approach (9,12). Starting and terminating points of each study segment containing the study lesion were carefully selected to match the corresponding landmarks on XRA and IVUS/VH (Fig. 2). Within each segment, we determined geometric and compositional parameters. Geometric parameters included minimal lumen diameter (MLD), %DS, minimal lumen area (MLA), and percentage of area stenosis (%AS). Percentage of atheroma volume (PAV) was calculated using the following equation: (total vessel area - total lumen area)/total vessel area. Compositional parameters included the volume and percentage of 3 components: calcified atherosclerotic plaque, HD-NCP, and LD-NCP. Between the outer vessel wall boundary and the luminal boundary, voxels were classified as CAP with attenuation values 150 HU (Hounsfield units) or greater, as HD-NCP with 30 to 149 HU and as LD-NCP with -100 to +30 HU. Total volume and percentage of each of the 3 components were measured in each study segment. Volume and percentage of NCP was calculated as the sum of HD-NCP and LD-NCP. We have previously evaluated and published inter-rater reliability for this approach (9,12,14,15).

**IVUS/VH IMAGE ANALYSIS.** Deidentified IVUS/VH datasets were transferred to a dedicated workstation and were analyzed using dedicated software (pcVH, version 3.0.394, Volcano Inc.) by an experienced cardiologist (G.V.). The luminal boundary and the external elastic lamina were contoured in a semiautomatic fashion in each frame. Based on a previously validated algorithm, the software classified each pixel as dense calcium (white color), fibrous (FI) tissue (green color), fibrofatty (FF) tissue (light green color), and necrotic core (NC) (red color) (Figs. 2F and 2G). Total volume and percentage of each of the 4 components was measured in the study segment. Furthermore, we calculated the volume and percentage of all NCP components (sum of NC, FF, and FI).

**Slice-by-slice image coregistration and analysis.** We performed a precise, slice-by-slice coregistration in a subset of patients with the best image quality based on the shape of the lumen on the respective modalities. After careful and

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**Figure 3. Slice-by-Slice Coregistration Between CTA and IVUS/VH**

Example of precisely coregistered IVUS (A, C) and CTA (B, D) datasets on a slice-by-slice basis. Slice-by-slice variation of MLA is tracked from the ostium of the coronary artery by CTA (green) and IVUS (red) before spatial coregistration (E) and after precise slice-by-slice spatial coregistration (F). ATL = ATLANTA study patient; other abbreviations as in Figures 1 and 2.
precise alignment of the starting and termination points of each segment on CTA and IVUS/VH, we identified completely matching slices between the 2 modalities and determined lumen area, vessel area, CAP area, and NCP area in each corresponding image pair (Fig. 3).

**Statistical methods.** Normally distributed continuous variables were expressed as mean ± SD and were compared by 2-tailed, unpaired t test, and non-normally distributed continuous variables were expressed as median (interquartile range) and were compared using the Mann-Whitney U test. Correlation was assessed by linear correlation; mean differences and limits of agreement were assessed by Bland-Altman analysis. A p value of 0.05 or less was considered statistically significant.

**PRIMARY END POINT.** The pre-specified primary end point of the study was the correlation between CTA and IVUS/VH for PAV measurements.

### Results

**Patient characteristics.** Of the 60 patients enrolled, 50 had corresponding, interpretable, simultaneous CTA and IVUS/VH datasets, excluding 10 patients from the analysis. In 5 of these 10 patients, the IVUS catheter could not be passed and in another 5 patients, the IVUS/VH image quality was not sufficient for quantitative analysis. Of the 10 patients that were excluded, 1 also had poor CT image quality. Demographic characteristics are shown in Table 1. In general, our population was typical for a population with no previous coronary artery disease who presented with new-onset symptoms, with a mean age of 58.7 ± 6.9 years.

**Study lesion data.** Of the 50 study lesions in 50 patients, 39 (78%) were in the left anterior descending, 5 (10%) in the left circumflex, and 6 (12%) in the right coronary artery; (78%) were in the left anterior descending, 5 (10%) in the left circumflex, and 6 (12%) in the right coronary artery; mean length of the analyzed segments was 26.8 ± 12.5 mm.

**Correlation between QCA and CTA.** Although mean differences for MLD and %DS were small between QCA and CTA, limits of agreement were wide (72% and 85% of the measurement, respectively) (Fig. 4) (Table 2).

**Correlation between CTA and IVUS/VH based on anatomical coregistration.** Scatterplots with regression lines and Bland-Altman plots for CTA and IVUS/VH parameters are shown in Figure 5 for geometric and in Figure 6 for plaque compositional parameters. Mean values, correlation coefficients, mean differences, and limits of agreement are shown in Table 3. Overall, there was statistically significant correlation for all parameters. Correlation was strongest for NCP volume (r = 0.84), CAP volume (r = 0.65), and MLA (r = 0.65) and was weakest for percentage of NCP (NCP-%) (r = 0.41) and for percentage of CAP (CAP-%) (r = 0.41).

**Correlation between CTA and IVUS/VH based on slice-by-slice coregistration.** We performed precise, slice-by-slice coregistration in 731 slices in 14 patients with the best image quality. Scatterplots with regression lines and Bland-Altman plots for lumen area, vessel area, and PAV are shown in Figure 7, revealing significant correlation for all 3 parameters on a slice-by-slice basis. Examples of simultaneous lumen and vessel wall measurements by CTA and IVUS/VH are shown in Figure 3, confirming that CTA-based measurements can accurately track the true slice-by-slice variation in lumen and vessel area as measured by IVUS/VH. Furthermore, there was significant correlation between CTA and IVUS/VH measurements of PAV (0.52 ± 0.13 and 0.54 ± 0.13 by CTA and IVUS, respectively; r = 0.51; p < 0.001). Mean values, correlation coefficients, mean differences, and limits of agreement are shown in Table 4. Scatterplots with regression lines and Bland-Altman plots for CAP area and NCP area are shown in Figure 8, revealing significant correlation for both parameters on a slice-by-slice basis. Overall, correlation was strongest for lumen area (r = 0.77) and vessel area (r = 0.72) and was weakest for NCP area (r = 0.46) and for CAP area (r = 0.43).

To explore plaque components on IVUS/VH that correspond to HD-NCP and LD-NCP on CTA, we compared...
correlation coefficients between CTA- and IVUS/VH-derived compositional parameters. This statistical analysis suggested that HD-NCP had the strongest correlation with FI by IVUS/VH, whereas LD-NCP correlated with the sum of NC + FF (Fig. 9).

**Discussion**

Our study has 3 significant aspects. First, to our knowledge, this is the first study that implemented a relatively complex design to include a detailed, multimodality approach to borderline coronary arterial lesions using 3 morphological methods. Second, we have used a combination of a previously validated, reproducible, 3-dimensional, segmental coregistration and a meticulous, slice-by-slice coregistration approach. Fully quantitative, 3-dimensional plaque measurements by CTA have not been validated against IVUS/VH in the past. Third, based on our 2-tiered approach, we answered a clinically relevant question about the accuracy of quantitative measurements using a commercial platform on a segmental basis and a research question about the accuracy of quantitative measurements on a slice-by-slice basis.

The first important finding is that based on a 3-dimensional, anatomical coregistration, there was significant correlation between CTA- and IVUS/VH-derived plaque geometric and compositional parameters (Fig. 2) (Table 3). Overall, mean differences for these parameters were relatively small, whereas the limits of agreement were wide, suggesting that such quantitative CTA parameters might be safely used in populations, whereas the predictive accuracy on a per-patient basis is limited. Limits of agreement between CTA and IVUS-VH for quantitative measurements of stenosis on a slice-by-slice basis were 50% to 54% and on a segmental basis were 66% to 97%. For quantitative measurements of plaque volume and compo-

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### Table 2. Segmental Correlation Between CTA and QCA Based on Anatomical Coregistration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Values</th>
<th>Correlation</th>
<th>Bland-Altman Analysis</th>
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<tr>
<td></td>
<td>CTA (Mean ± SD)</td>
<td>QCA (Mean ± SD)</td>
<td>p Value for t Test</td>
</tr>
<tr>
<td>MLD, mm</td>
<td>1.6 ± 0.6</td>
<td>1.8 ± 0.6</td>
<td>0.12</td>
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<tr>
<td>%DS</td>
<td>47.5 ± 17.2</td>
<td>47.1 ± 15.1</td>
<td>0.88</td>
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CTA = computed tomography angiography; MLD = minimal lumen diameter; QCA = quantitative coronary angiography; %DS = percentage of diameter stenosis.
sition, limits of agreement on a segmental basis were 47% to 137% and on a slice-by-slice basis were 122% to 224%. These wide limits of agreement indicate that using the present acquisition and reconstruction techniques, and with the present post-processing methods, such quantitative CTA-derived measurements may not be precise enough for clinical use in individual patients. By contrast, because correlation was moderate to good between CTA- and IVUS/VH-derived parameters, and because mean differences were small, quantitative CTA measurements may be used in population-based research studies, with adequate sample size calculations.

Calcium blooming in the region of maximal stenosis leads to 21% underestimation of MLD by CTA, whereas $\%$DS is overestimated by 39%, as there is typically less calcium and, therefore, less blooming in the area of the reference segment. Blooming of iodine in the lumen leads to 27% overestimation of MLA by CTA, but as this is uniform along the vessel, $\%$AS was only underestimated by 5%. The NCP volume had the strongest correlation ($r = 0.84$), but it was overestimated on CTA by 38%. The most important limitation of CTA-based plaque quantification is the overestimation of calcified plaque volume and percentage, by

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**Figure 5. Scatterplots and Bland-Altman Plots for Geometric Parameters, Based on Anatomical Coregistration**

Scatterplots illustrate modest correlation between CTA and IVUS for MLD, $\%$DS, MLA, and percentage of area stenosis ($\%$AS). Bland-Altman plots show small mean differences with relatively wide limits of agreement. Abbreviations as in Figures 1, 2, and 4.

**Figure 6. Scatterplots and Bland-Altman Plots for Compositional Parameters, Based on Anatomical Coregistration**

Scatterplots illustrate modest to good correlation between QCA and CTA for noncalcified plaque (NCP) volume, percentage of NCP ($\%$NCP), calcified plaque (CP) volume, and percentage of CP ($\%$CP). Bland-Altman plots show small mean differences with relatively wide limits of agreement. CAP = calcified atherosclerotic plaque; other abbreviations as in Figures 1 and 2.
104% and by 64%, respectively. It is important to point out that our patients were selected with an intermediate stenosis; therefore, our data may lack the more extreme values on either side of the population mean. This may contribute to the relatively low correlation coefficients in our sample. We also found that CT had increasing degrees of overestimation of plaque volumes with true increases in plaque volume as shown by IVUS, presumably because there are more blooming artifacts (data not shown).

The second important finding is that there was significant correlation between CTA and IVUS/VH measurements of lumen area, vessel area, PAV, NCP, and CAP in spatially coregistered slices. Correlation coefficients for lumen area and vessel area (0.77 and 0.72, respectively) indicate that CTA can track the slice-by-slice variation in lumen and vessel area reasonably well. By contrast, lower correlation coefficients for CAP area, NCP area, and PAV (0.43, 0.46, and 0.51, respectively) indicate that CT’s ability for plaque quantification is still somewhat limited (Fig. 3) (Table 4). Similar to the segmental findings, CTA slightly overestimated lumen and vessel area by 22% and 19%, respectively. Although NCP area was only moderately overestimated on CTA (by 44%), CAP area was overestimated by 88%. Importantly, mean PAV by CT and IVUS were 0.52 and 0.54, respectively (r/H11005 0.51; p/H11021 0.001), satisfying the primary end point and confirming the primary hypothesis of our study.

Finally, our statistical analysis suggested that HD-NCP best correlates with FI and LD-NCP correlates with the...
sum of NC + FF on IVUS/VH. These statistical findings are hypothesis-generating and need true imaging-based validation by evaluating the spatial overlap between these structures on CTA and IVUS/VH.

Our study adds significantly to the current literature on the accuracy of CTA for coronary plaque quantification. Leber et al. (11) previously showed in an initial feasibility study using manual plaque delineation that correlation was moderate between CTA and IVUS-derived plaque quantification ($r^2 = 0.69$) with relatively wide limits of agreement (11), and that there was significant overlap in CTA-derived tissue attenuation values between hypoechoic and hyperechoic NCP (49 ± 22 HU and 91 ± 22 HU) (10). In 47 patients in a substudy of the PROSPECT (Providing Regional Observations to Study Predictors of Events in the Coronary Tree) trial, Otsuka et al. (16) found good correlation between CTA- and IVUS-derived plaque measurements with relatively wide limits of agreement. A small study by Sun et al. (17) without true anatomical or spatial coregistration found modest correlation between CTA and grayscale IVUS datasets for luminal cross-sectional area and for plaque

<table>
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<tr>
<th>Table 4. Slice-by-Slice Coregistration Between CTA and IVUS/VH</th>
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<td><strong>Mean Values</strong></td>
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<tr>
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<tr>
<td>Lumen area, mm²</td>
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<td>CAP area, mm²</td>
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<td>NCP area, mm²</td>
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CAP = calcified plaque; NCP = noncalcified plaque; PAV = percentage of atheroma volume; other abbreviations as in Tables 2 and 3.

Figure 8. Scatterplots and Bland-Altman Plots for Compositional Parameters, Based on Slice-by-Slice Coregistration of CTA and IVUS/VH

Scatterplots illustrate modest correlation for CP area and NCP area. Bland-Altman plots show that both components are overestimated by CTA. Abbreviations as in Figures 1, 2, and 6.
cross-sectional area. In another small study, Joshi et al. (18) showed that CTA and IVUS were much better correlated than QCA and CTA. Our study expanded on these findings and showed better correlation between QCA- and CTA-derived MLD and %DS, probably given the more standardized, validated approach we used for CTA analysis (16,18).

Pundziute et al. (19) showed that compared with calcified plaques, NCPs contained more FI and FF tissue on IVUS/VH, whereas mixed and calcified plaques contained more dense calcium, compared with NCPs. Furthermore, IVUS/VH-based thin cap fibroatheromas were most frequent in mixed plaques (32%) (19,20). Our study expands significantly on these findings, because we also precisely quantified plaque components on CTA.

An important clinical implication of the present study is that it confirmed that when quantitative plaque analysis of CTA datasets is performed using a commercially available post-processing workstation with a standardized approach on a segmental basis, CTA-derived MLD, %DS, MLA, %AS, and NCP correlate significantly with IVUS/VH measurements in a population, but not on a per-patient basis. Given this degree of validation of CTA, quantitative plaque parameters may be incorporated in carefully designed clinical studies for the assessment of coronary atherosclerosis (14).

Study limitations. Although this was a complex, prospective study with a pre-specified primary end point, it has several limitations. First, CTA studies at baseline were performed on a 64-slice scanner system; today, there are newer-generation scanners available. The current phase of our study is performed on a 320-multidetector-row system. Second, our study lesions were limited to 40% to 70% stenoses; the current, ongoing second phase of the study is enrolling patients with 71% to 99% stenoses. The lack of more extreme values around the population mean may have contributed to the observed lower correlation coefficients for some of the measurements. Finally, 10 of the 60 prospectively

![Figure 9. Correlation for HD-NCP and LD-NCP Against IVUS/VH Parameters](image-url)

Scatterplots illustrate modest correlation between high-density (HD) NCP and fibrous (FI) tissue and poor correlation between low-density (LD) NCP and fibro-fatty (FF) tissue plus necrotic core (NC). Bland-Altman plots show that these components are overestimated by CTA. Abbreviations as in Figures 1 and 6.
enrolled patients were excluded from the final analysis because of technical problems; this may have introduced some bias.

Conclusions

To our knowledge, this was the first prospective study to implement a 3-dimensional, quantitative analysis of coregistered CTA and IVUS/VH datasets for the assessment of nonobstructive coronary arterial plaques. We found significant correlation between CTA and IVUS/VH with small mean differences, suggesting that quantitative CTA measurements may be used in population-based approaches. However, the relatively wide limits of agreement suggest that CTA quantification should only supplement, and not replace, the clinically used, more descriptive interpretations. Coronary CTA is a promising, emerging tool for the quantification of coronary arterial atherosclerotic plaques.

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REFERENCES


Key Words: atherosclerosis • coronary computed tomography angiography • intravascular ultrasound.