Original Research Article

Dual-energy computed tomography imaging to determine atherosclerotic plaque composition: A prospective study with tissue validation

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A B S T R A C T

Background: Identifying vulnerable coronary plaque with coronary CT angiography is limited by overlap between attenuation of necrotic core and fibrous plaque. Using x-rays with differing energies alters attenuation values of these components, depending on their material composition.

Objectives: We sought to determine whether dual-energy CT (DECT) improves plaque component discrimination compared with single-energy CT (SECT).

Methods: Twenty patients underwent DECT and virtual histology intravascular ultrasound (VH-IVUS). Attenuation changes at 100 and 140 kV for each plaque component were defined, using 1088 plaque areas co-registered with VH-IVUS. Hounsfield unit thresholds that best detected necrotic core were derived for SECT (conventional attenuation values) and for DECT (using dual-energy indices, defined as difference in Hounsfield unit values at the 2 voltages/their sum). Sensitivity of SECT and DECT to detect plaque components was determined in 77 segments from 7 postmortem coronary arteries. Finally, we examined 60 plaques in vivo to determine feasibility and sensitivity of clinical DECT to detect VH-IVUS–defined necrotic core.

Results: In contrast to conventional SECT, mean dual-energy indices of necrotic core and fibrous tissue were significantly different with minimal overlap of ranges (necrotic core, 0.007 [95% CI, −0.001 to 0.016]; fibrous tissue, 0.028 [95% CI, 0.016–0.050]; \( P < .0001 \)). DECT increased diagnostic accuracy to detect necrotic core in postmortem arteries (sensitivity, 64%; specificity, 98%) compared with SECT (sensitivity, 50%; specificity, 94%). DECT

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1. Introduction

Rupture-prone coronary atherosclerotic plaques typically have a large necrotic core and thin fibrous cap; differentiation of these features is therefore critical for imaging modalities to identify potentially high-risk plaques. Although coronary CT angiography (CTA) can identify some plaque features that predict acute coronary syndrome, such as positive arterial remodeling and low-attenuation areas of plaque, more precise identification requires better discrimination of these components from each other. Plaque elements can be characterized by their CT attenuation profiles; however, studies that used conventional single-energy CT (SECT) found limiting overlap of the attenuation ranges of necrotic core and fibrous plaque. Tissue attenuation profiles are determined both by physical properties of constituent elements (atomic number and density) and by delivered x-ray energy. For example, dual-energy CT (DECT) provides differing attenuation of materials at 2 different energies and can differentiate fatty liver from tumor or can determine the composition of renal stones. In theory, DECT should further separate attenuation values of coronary plaque components, allowing easier differentiation. Indeed, 2 separate sequential scans with different energies on ex vivo coronaries showed that calcified plaques had the largest and lipid-rich plaques the least difference in attenuation on DECT. However, the ability of DECT to differentiate necrotic core from fibrous tissue has never been tested. Furthermore, sequential scanning cannot be used for rapidly moving coronary arteries, and the ability of DECT to identify plaque composition in vivo is unknown. The 2-tube, 2-detector configuration of dual-source scanners allows acquisition of 2 temporally registered data sets of different energies. We therefore determined whether DECT could differentiate plaque components better than SECT and to identify these components ex vivo against postmortem histology and in vivo against virtual histology intravascular ultrasound (VH-IVUS).

2. Methods

2.1. Study protocol

The local institutional review board approved the entire study, and participants gave fully informed consent. Subjects with stable angina or acute coronary syndrome underwent both VH-IVUS and coronary CTA with data sets used initially for derivation and then validation of DECT plaque analysis. VH-IVUS was acquired with Eagle-Eye Gold catheters (Volcano Corporation, San Diego, CA) as described previously. CT data were acquired with a Somatom Definition 64-slice dual-source machine (Siemens, Germany). Intravenous metoprolol was administered if heart rate was >65 beats/min. Images were acquired simultaneously at 140 kV, 82 mAs (tube A) and 100 kV, 164 mAs (tube B) with 64 × 0.6-mm collimation. A triphasic injection protocol with intravenous contrast (iopamidol [Niopam 370]; Bracco, UK) was used after a 20-mL timing bolus.

2.2. Co-registration of DECT and VH-IVUS plaque components

CT image analysis was performed with Circulation III software (Siemens). Curved multiplanar coronary artery reconstructions were compared with longitudinal reconstructed IVUS data sets. To facilitate plaque component sampling VH-IVUS was used to identify plaque cross-sectional images that were either predominantly fibrous plaque or contained a large confluent necrotic core or dense calcification as previously described. These plaque locations were co-registered from IVUS to coronary CTA by triangulation with the use of reference measurements from coronary ostia and side branches (Fig. 1). Areas of hypoattenuating or hyperattenuating plaque on cross-sectional coronary CTA images were classified as necrotic core, fibrous plaque, or calcified plaque, depending on matched corresponding VH-IVUS frames. Attenuation was sampled at 8 points distributed throughout these areas and lumen, to give mean CT attenuation values (Hounsfield units) (Fig. 2). DECT acquisition yielded 2 data sets with matching attenuation values at different energies for each plaque component.

2.3. Validation of necrotic core detection with DECT

2.3.1. Postmortem validation

The left anterior descending artery was dissected in 10 autopsy hearts within 24 hours of death with 40 to 50 mm of surrounding tissue to maintain structural integrity. Vessels were wax-embedded for mechanical support, and the left main stem ostium and distal left anterior descending artery were cannulated. Seven of 10 arteries were suitable for imaging (occluded arteries were not used). Vessels were submerged and pressure-perfused with phosphate-buffered saline at 37°C at 100 mm Hg. DECT acquisition was performed with the same peak tube voltages as in vivo, using contrast diluted to achieve luminal attenuation comparable with in vivo scans.

After imaging, arteries were fixed with formalin, and the external surface was marked at 1-cm intervals to aid co-registration. Each 1-cm coronary artery block was cut into segments 400 μm in length, processed for histology, sectioned...
at 5-μm intervals, and stained with hematoxylin and eosin and Movat’s pentachrome stains. A histopathologist (M.G.) then identified any plaque areas that contained necrotic core with no minimum cutoff size, as long as a confluent core was discernable within the plaque. Sequential 400-μm segments of coronary CTA images co-registered with histology were

Fig. 1 — Co-registration between VH-IVUS and 140 kV/100 kV DECT. Longitudinal (left) and cross-sectional (right) images for VH-IVUS and co-registered DECT at 100 kV and 140 kV. Calcified plaque is identified 5 mm from a side branch adjacent to characteristic calcification (yellow line). A cross section is taken through this plaque (blue arrow), and, after orientation with the VH-IVUS cross-section region of interest, sampling to obtain Hounsfield unit was performed in the calcified plaque (asterisk). Green indicates fibrous plaque; red, necrotic core; white, calcified plaque. DECT, dual-energy CT; HU, Hounsfield unit; VH-IVUS, virtual histology intravascular ultrasound.

Fig. 2 — Attenuation sampling of VH-IVUS–defined necrotic core. (A) Cross section of coronary CTA with attenuation sampling in hypoattenuated area of noncalcified plaque (B). (C) Co-registered VH-IVUS slice shows that sampled area contains significant necrotic core (red). Green indicates fibrous plaque; white, calcified plaque. CTA, CT angiography; VH-IVUS, virtual histology intravascular ultrasound.
analyzed. Initially a single-energy data set was used (100 kV) to identify all visible coronary plaques. Attenuation was sampled throughout all noncalcified plaque and identified as necrotic core if any attenuation values were lower than the threshold attributed to necrotic core. Matching attenuation values were also sampled in the 140-kV data set and used to create a dual-energy index (DEI) with the use of a formula used previously\(^7\) which maximizes the difference in attenuation at 100 kV (\(x_{100}\)) and 140 kV (\(x_{140}\)) by dividing the difference in Hounsfield unit values at the 2 peak voltages by their sum, with individual attenuations shifted by 1000 HU to avoid negative values.

\[
\text{DEI} = \frac{(x_{100} + 1000 \text{ HU}) - (x_{140} + 1000 \text{ HU})}{(x_{100} + 1000 \text{ HU}) + (x_{140} + 1000 \text{ HU})}
\]

Plaque was classified as necrotic core by DECT if the DEI was in the range attributed to necrotic core.

2.3.2. Feasibility of clinical DECT

The image quality of all in vivo scans was assessed with the following 4-point scoring system\(^9\): 1, nondiagnostic; 2, adequate image quality to rule out significant stenosis but significant artifact present; 3, good image quality with any artifact present not interfering with assessment of calcified or noncalcified plaque; and 4, excellent images with complete absence of artifact. Image noise was defined as the standard deviation of attenuation (HU) in a 5-mm\(^2\) sampled area placed within the aortic root. Effective radiation doses were calculated with the standard organ weighting factor for the chest (\(\kappa = 0.0014 \text{ mSv}\)).

2.3.3. In vivo validation

VH-IVUS was performed in all 3 coronary arteries, and all plaques detected in vivo were co-localized with equivalent plaques on coronary CTA by using the triangulation method (Fig. 1). Plaque was analyzed by coronary CTA frame by frame, and attenuation was sampled throughout all noncalcified plaques. Necrotic core was identified by SECT if any attenuation values at 100 kV were lower than the threshold attributed to necrotic core, and by DECT if the DEI was in the range attributed to necrotic core. The accuracy of coronary CTA to determine the presence of necrotic core was compared with standard VH-IVUS definitions (plaque containing >10% VH-IVUS–defined confluent necrotic core for 3 consecutive frames\(^1\)).

2.4. Statistical analysis

Statistical analysis was performed with R software (R Core Team [2013]; R Foundation for Statistical Computing, Austria). Continuous variables are presented as means \(\pm\) SD if normally distributed and medians [interquartile ranges] if not. Attenuation values and DEIs were expressed as box and whisker plots. Differences in plaque component attenuation and DEIs were assessed with a linear mixed effects model (to account for multiple values per patient) with plaque component and kilovolt value as fixed effects, patient as a random effect, and assuming a compound symmetry structure. Plaque component was included in the model as an explanatory factor variable with 4 levels (necrotic core, fibrous plaque, lumen, and calcified plaque) with necrotic core as the reference category. Measurements of accuracy are expressed as point estimates of sensitivity, specificity, and diagnostic accuracy.

3. Results

3.1. Defining plaque components with DECT

We first established DECT attenuation ranges for plaque components (defined by VH-IVUS). Twenty patients underwent coronary CTA and 3-vessel VH-IVUS, and 1104 regions of interest (ROIs) were sampled from 138 plaque cross sections (69 at 100 kV and 69 at 140 kV), providing paired attenuation values at 100 kV (552 ROIs) and 140 kV (552 ROIs) (95 necrotic cores, 85 fibrous tissues, 230 calcified plaques, and 142 lumens; Table 1). Compared with necrotic core, lumen attenuation was higher at both 100 kV (mean difference, 350.9 HU; 95% CI, 253.1–448.7 HU) and 140 kV (mean difference, 237.7 HU; 95% CI, 160.8–315.4 HU; \(P < .0001\)). Similar differences were found between calcified plaque and necrotic core at both 100 kV (mean difference, 671.6 HU; 95% CI, 582.7–760.5 HU) and 140 kV (mean difference, 535.3 HU; 95% CI, 465.4–605.2 HU; \(P < .0001\)). However, neither of the conventional single energies completely separated fibrous plaque from necrotic core (mean difference at 100 kV, 107.8 HU; 95% CI, −0.19 to 215.9 HU; \(P = .05\); and mean difference at 140 kV, 51.1 HU; 95% CI, −33.9 to 136.0 HU; \(P = .233\)).

Tissue attenuation values are different at 100 kV and 140 kV, and this difference is greater for some plaque components than others. To increase sensitivity of DECT to detect differences in plaque components, we calculated their DEI as previously defined.\(^7\) DEIs for each component were necrotic core (0.007 ± 0.006), fibrous plaque (0.028 ± 0.011), lumen (0.048 ± 0.016), and calcified plaque (0.059 ± 0.028). Importantly, DEIs of necrotic core were significantly different for both fibrous plaque (mean difference, 0.023; 95% CI, 0.008–0.037) and calcified plaque (mean difference, 0.039; 95% CI, 0.027–0.051; \(P < .0001\)). DEI ranges overlapped significantly for lumen (0.028–0.081) and calcified plaque (0.013–0.096), lumen and fibrous plaque (0.016–0.050), and fibrous plaque

<table>
<thead>
<tr>
<th>Table 1 – Attenuation values (HU) of VH-IVUS–defined plaque components at 100 kV and 140 kV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Necrotic core</td>
</tr>
<tr>
<td>100 kV</td>
</tr>
<tr>
<td>140 kV</td>
</tr>
<tr>
<td>Fibrous plaque*</td>
</tr>
<tr>
<td>100 kV</td>
</tr>
<tr>
<td>140 kV</td>
</tr>
<tr>
<td>Lumen*</td>
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<tr>
<td>100 kV</td>
</tr>
<tr>
<td>140 kV</td>
</tr>
<tr>
<td>Calcified plaque*</td>
</tr>
<tr>
<td>100 kV</td>
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<tr>
<td>140 kV</td>
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</tbody>
</table>

HU, Hounsfield unit; VH-IVUS, virtual histology intravascular ultrasound.

* Significant difference in the attenuation of plaque components at 100 kV and 140 kV (\(P < .05\), Dunn’s multiple comparison test).
and calcified plaque. However, DEI ranges for necrotic core (−0.001 to 0.016) did not overlap with any other component, in contrast to the marked overlap of necrotic core and fibrous tissue ranges with both single energies 100 kV (37–219 HU) and 140 kV (39–121 HU; Fig. 3). We therefore used a DEI of 0.016 as a cutoff between necrotic core and fibrous plaque to discriminate plaque with necrotic core.

### 3.2. Postmortem validation of DECT

Having established attenuation ranges and DEIs for each plaque component, we tested their ability to identify components ex vivo in 7 coronary arteries. Fifty-four of 77 segments (70%) contained atherosclerotic plaques with 28 of 77 segments (36%) containing a necrotic core. Attenuation was sampled throughout all noncalcified plaque in co-registered segments by using the 100-kV data set. Because SECT attenuation ranges for necrotic core and fibrous plaque overlapped, no single Hounsfield unit threshold could separate them completely. We therefore examined the accuracy of 3 different thresholds (<37 HU, <93 HU, and <138 HU) to define necrotic core. The threshold of <37 HU was selected because it is less than all attenuation values found in fibrous plaque (37–254 HU; Table 1) and similar to thresholds suggested previously (<30 HU) that prospectively predicts adverse events. The interquartile ranges (IQRs) of necrotic core and fibrous plaque were 29 to 81 HU and 104 to 185 HU, respectively. Thus, <93 HU was selected as a threshold because it bisects the upper value of necrotic core IQR (81) and the lower value of fibrous plaque IQR (104) and hence should include ≥75% necrotic core and exclude all but ≤25% fibrous tissue with the lowest attenuation. Finally, the upper value of the 95th percentile for necrotic core attenuation values was 138 HU, so <138 HU was selected (Table 1).

The sensitivity, specificity, and accuracy of these attenuation values to identify necrotic core were 25%, 98%, and 71%, respectively, for <37 HU; 50%, 94%, and 78%, respectively, for <93 HU; and 68%, 80%, and 75%, respectively, for <138 HU (Table 2). We next examined whether DEIs could better discriminate necrotic core and fibrous tissue compared with 100-kV SECT on plaques with borderline attenuation values, defined as >37 HU (the lowest fibrous plaque attenuation) and <219 HU (the highest necrotic core attenuation). A DEI <0.016 led to correct detection of necrotic core in 18 of 28 segments, with a sensitivity, specificity, and accuracy of 64%, 98%, and 86%, respectively (Table 2). Thus, DEIs improved discrimination of necrotic core and fibrous tissue compared with SECT (Fig. 4).

### 3.3. In vivo validation of DECT with VH-IVUS

Better discrimination of necrotic core from fibrous tissue ex vivo suggests that DECT may better identify these components in vivo and thus provide additional coronary CTA features of unstable plaques. However, in vivo DECT has poorer image quality, potentially reducing its clinical utility. We therefore examined both ability to identify VH-IVUS–defined plaque components and image quality in 20 patients undergoing DECT. Baseline patient and scan parameters were mean heart rate of 64 ± 9.4 beats/min, mean scan quality of 1.9 ± 0.7 (scale, 1–4), mean noise of 16.8 ± 4.6 HU, and mean dose-length product of 663.7 ± 119.3 mGy ∙ cm, giving a mean effective dose of 7.8 ± 3.8 mSv. In comparison with conventional SECT at our institute, no difference was found in the mean image noise of DECT vs SECT (16.8 ± 4.6 HU vs 16. ± 6.2 HU; P = .85), but DECT displayed significantly lower image quality (mean quality score, 1.9 vs 3.4). Three-vessel VH-IVUS yielded 60 plaques from 20 patients. In 18 of the 60 co-registered plaques, DECT image quality was too poor to allow plaque analysis. Of the remaining 42 plaques, VH-IVUS found that 31 plaques (74%) contained significant necrotic core. The most accurate attenuation threshold for necrotic core (<93 HU) in the SECT 100-kV data set detected necrotic core with a 39% sensitivity, 91% specificity, 92% positive predictive value, 34% negative predictive value (NPV), and 52% diagnostic accuracy. The addition of DEIs detected necrotic core with 45% sensitivity, 91% specificity, 94% positive predictive value, 37% negative predictive value, and 57% diagnostic accuracy.

### 4. Discussion

Identification of necrotic core is central to identifying high-risk vulnerable plaques, including thin-cap fibroatheromas...
(TCFAs) whether by postmortem histology\(^1\) or in vivo with VH-IVUS.\(^{11}\) Coronary CTA can identify lipid pools as large areas of hypodense plaque (>2 mm\(^2\)),\(^{13}\) and low-attenuation plaque surrounded by higher attenuation noncalcified plaque; the napkin-ring sign is associated with larger necrotic cores on histology.\(^{14}\) However, this CT sign still only identified 44% of optical coherence tomography defined TCFA.\(^{15}\) Better discrimination of necrotic core from fibrous tissue by CTA is required if it is to be more widely used as a tool for patient risk stratification. The spatial resolution of modern CT scanners at 0.4 mm is sufficient to detect average-sized necrotic cores in most ruptured plaques (2.2 mm\(^2\)) and nonruptured TCFAs (1.1 mm\(^2\)).\(^{16}\) Thus, detecting necrotic core depends on better discrimination from fibrous tissue.

We first defined attenuation ranges that represent different plaque components by using co-registered VH-IVUS. Although VH-IVUS has some limitations, we recently found diagnostic accuracies of >74% for VH-IVUS to classify all plaques.\(^7\) SECT showed significant overlap between attenuation ranges of necrotic core and fibrous plaque. At diagnostic energies, x-ray attenuation depends on both photoelectric absorption, which depends on atomic number, and Compton scatter, which depends on density of the material. These interactions alter according to the delivered energy. Lipid-rich necrotic core has a lower atomic number than calcium in plaque and a lower density than fibrous tissue and resulted in both the lowest attenuation values and the smallest change in attenuation at different energies. With the use of the attenuation at 2 energies to create DEIs we found that the DEI of necrotic core was significantly lower than fibrous plaque and calcified plaque, and, importantly, there was no overlap in necrotic core and fibrous plaque DEIs. This is in contrast to a previous postmortem coronary DECT study by Barreto et al\(^7\) which found no significant difference. Like us, Barreto et al\(^7\) found a significant change in attenuation of fibrous plaque at different x-ray energies but not lipid-rich necrotic core. However, although Barreto et al\(^7\) found that the DEI of lipid-rich plaque was lower than fibrous plaque, it was not statistically significant. This may be due to a number of factors. First, only 3 lipid-rich plaque areas were sampled, resulting in reduced power to detect any difference. In addition, lipid-rich plaque was located on 5-μm thick histology samples, orders of magnitude thinner than the reconstructed slice thickness of coronary CTA. If the lipid-rich plaque was small, the area sampled by CT

### Table 2 – Ex vivo diagnostic accuracy of CT characterization of necrotic core.

<table>
<thead>
<tr>
<th>Attenuation Range</th>
<th>Sensitivity correctly identified, % (95% CI) [n/N]</th>
<th>Specificity correctly excluded, % (95% CI) [n/N]</th>
<th>PPV, % (95% CI)</th>
<th>NPV, % (95% CI)</th>
<th>Accuracy, % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;37 HU</td>
<td>25 (11–45) [7/28]</td>
<td>98 (89–100) [48/49]</td>
<td>88 (47–98)</td>
<td>70 (57–80)</td>
<td>71 (60–81)</td>
</tr>
<tr>
<td>&lt;93 HU</td>
<td>50 (31–69) [14/28]</td>
<td>94 (83–99) [46/49]</td>
<td>82 (57–96)</td>
<td>77 (64–87)</td>
<td>78 (67–87)</td>
</tr>
<tr>
<td>DECT (if HU &lt; 219)</td>
<td>64 (44–81) [18/28]</td>
<td>98 (89–100) [48/49]</td>
<td>95 (74–99)</td>
<td>83 (71–91)</td>
<td>86 (76–93)</td>
</tr>
</tbody>
</table>

DECT, dual-energy CT; DEI, dual-energy index; NPV, negative predictive value; PPV, positive predictive value; SECT, single-energy CT.

**Fig. 4** – DECT imaging compared with postmortem histology. Volume-rendered DECT reconstruction (middle) of postmortem coronary artery with attenuation sampling of noncalcified plaque at 100 kV (158 HU) and 140 kV (153 HU) (left). These attenuation values are above the threshold required to classify necrotic core; however, the DEI (0.002) correctly identifies the NC confirmed by histology (right). DECT, dual-energy CT; DEI, dual-energy index; HU, Hounsfield unit; LU, lumen; NC, necrotic core.
may have included other tissue types. We derived attenuation values from VH-IVUS, requiring a large (> 10% plaque volume) confluent necrotic core on a VH-IVUS slice (approximately 150 μm). This comparable sample sizes may make it more likely that the CT sampled area contained predominantly necrotic core rather than other plaque types.

We used DEIs to examine the ability of DECT to identify necrotic core compared with histology in postmortem coronary arteries. Previous SECT studies defined necrotic core with a low attenuation threshold (30 HU) to prevent false positives. Indeed, < 37 HU gave excellent specificity (98%) but low sensitivity (25%), whereas < 138 HU increased sensitivity but markedly reduced specificity. The highest diagnostic accuracy was achieved by using < 93 HU; however, the use of DECT improved both sensitivity and specificity for detecting necrotic core.

Finally, we examined the ability of DECT to identify plaque components against VH-IVUS in vivo. The use of dual-source CT in dual-energy mode to create 2 independent data sets reduces its temporal resolution from 83 milliseconds to 165 milliseconds, but whether this negates any additional information gained from attenuation changes detected by DECT is unknown. DECT scans were performed with retrospective acquisitions, explaining the relatively high radiation exposures albeit still lower than median doses reported in clinical practice. Although DECT produced a modest benefit in diagnostic accuracy to differentiate necrotic core vs SECT, the clinical utility of DECT was severely limited by loss of image quality.

This study was designed to examine the ability of DECT to identify plaque components, specifically to discriminate necrotic core from fibrous tissue. However, there are limitations to our study. First, the same patients were used for both derivation and validation (although analyzed per cross section vs per plaque). Diagnostic accuracy results may be worse if validation is applied in a completely independent sample. Second, blooming artifact of high attenuation structures means that identifying true boundaries of calcified plaque can be difficult. Combined with reduced quality of in vivo DECT, this may affect accuracy of attenuation values obtained in some calcified plaque areas and may explain the similar DEIs of lumen and calcified plaque despite differences in atomic numbers of iodine and calcium. Image quality may be better with slower heart rates, although the acquisition protocols used reflect current clinical practice. Third, DEI differences may be greater if 80 kV, not 100 kV, was used as the lower x-ray energy. However, the use of 80 kV in our in vivo population would increase image noise with potential loss of image interpretability. Fourth, ex vivo validation was based on only 7 coronary arteries; nevertheless, these arteries yielded 77 segments, including 28 with necrotic core. Fifth, the accuracy of SECT was tested with the use of fixed attenuation thresholds. However, attenuation of coronary structures may alter, depending on body habitus, and attenuation of plaque may vary according to adjacent contrast intensity, especially in more vascular plaques with developed vasa vasaorum. The accuracy of SECT may be increased if attenuation thresholds were standardized according to aortic attenuation and modified to take into account luminal contrast intensity. Finally, the clinical study compared SECT with DECT. However, because of constraints on radiation exposure, the 100-kV data set from DECT was used to represent SECT. Although 100 kV is a recognized voltage for clinical use, the temporal resolution in the 100-kV DECT data set is lower than in conventional SECT. The diagnostic accuracy to detect necrotic core by using DEIs was lower in vivo than in postmortem samples. In vivo images can be degraded by mechanisms such as beam hardening, scatter from adjacent structures, and the effect of the lower temporal resolution of DECT on moving coronary arteries. Although newer dual-source DECT scanners have improved temporal resolution, whether this negates the loss of accuracy of DECT plaque analysis in vivo is unknown.

In summary, coronary CTA imaging with 2 energy levels permitted better resolution of necrotic core and fibrous plaque than single-energy coronary CTA. Dual energy also improves accuracy in classifying plaque components ex vivo. Although this suggests that DECT may identify vulnerable atherosclerotic plaques with more precision than single energy, its clinical usefulness in our study was limited by inferior temporal resolution. Nevertheless, improvements in CT technology with better temporal resolution mean that DECT is worthy of future evaluation in prospective trials to aid prediction of future coronary events.

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