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Characterization of Complex Coronary Artery Stenosis Morphology by Coronary Computed Tomographic Angiography

Brett M. Wertman, MD,* Victor Y. Cheng, MD,*† Saibal Kar, MD,* Heidi Gransar, MS,*† Ryan A. Berg, MD,* Hursh Naik, MD,* Rajendra Makkar, MD,* John D. Friedman, MD,*†‡ Jay N. Schapira, MD,* Daniel S. Berman, MD*†‡

Los Angeles, California

OBJECTIVES This study sought to assess the ability of coronary computed tomography angiography (CTA) in identifying complex coronary stenosis morphology before invasive coronary angiography (ICA) and percutaneous coronary intervention (PCI).

BACKGROUND Complexity of stenosis morphology affects PCI success. Whether CTA can detect the entire spectrum of recognized complex stenosis morphologies has not been investigated.

METHODS All nonbypassed, nonstented, ≥2-mm–diameter native coronary arterial segments in 85 consecutive patients who underwent ICA ≤30 days after CTA were assessed. Two blinded CTA readers qualitatively and quantitatively evaluated all lesions ≥70% stenotic by visual inspection and characterized each as type C or nontype C, according to the modified American College of Cardiology morphology criteria for estimating PCI risk. Results were compared with ICA data similarly analyzed by 2 blinded interventional cardiologists. The PCI procedure duration and contrast use were compared between type C and nontype C lesions identified on both ICA and CTA.

RESULTS CTA detected 84 of 93 lesions (90%) causing ≥70% stenosis on ICA and correctly characterized 42 of 53 lesions (79%) found to concurrently show type C morphology on ICA. Type C features most frequently missed by CTA were ostial involvement (5 cases) and lesion length >20 mm (7 cases). Major branch involvement was the most frequent false-positive type C feature (12 cases). Mean PCI duration in patients with and without type C lesions on CTA were 42.4 ± 24.7 min and 21.5 ± 13.3 min ($p = 0.009$), respectively; mean total contrast used were 263 ± 150 ml and 140 ± 47 ml ($p = 0.007$), respectively.

CONCLUSIONS In vessels segments ≥2 mm in diameter, CTA can predict lesions likely to reach ≥70% stenosis on ICA and provide added value in discerning complex morphologies associated with these lesions. Presence of complex, severely obstructive lesions on CTA is associated with higher contrast use and greater procedure length during PCI. (J Am Coll Cardiol Img 2009;2:950–8) © 2009 by the American College of Cardiology Foundation

From the *Division of Cardiology, Department of Medicine, and †Department of Imaging, Cedars-Sinai Medical Center, Los Angeles, California; and the ‡Department of Medicine, David Geffen School of Medicine, University of California, Los Angeles, California. Supported by a grant from the Lincy Foundation, Beverly Hills, California. Drs. Wertman and Cheng contributed equally to this work.

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After a multitude of studies have established the accuracy of coronary computed tomographic angiography (CTA) in detecting ≥50% coronary arterial stenosis (1–7), similar evidence for ≥70% stenosis is beginning to emerge (8). Finding a ≥70%, "severe" stenosis often generates increased consideration for revascularization, including the prospect of percutaneous coronary intervention (PCI). One important factor that impacts the PCI success rate is the complexity of stenosis morphology (9,10), and the utility of CTA in describing morphology of ≥70% stenoses has not been systematically studied. We sought to assess the use of CTA in characterizing complex morphologic features of such lesions by applying standard criteria associated with increased risk of complication from PCI, and in predicting associated procedure length and contrast use during PCI.

METHODS

Patient population. We identified 86 consecutive patients who underwent invasive coronary angiography (ICA) within 30 days after coronary CTA (median 6 days) from September 2006 to October 2007. One patient in whom none of the coronary tree was adequately opacified because of inappropriate contrast timing was excluded. The remaining 85 patients composed the study population.

CTA image acquisition. The CTA scan was performed on the dual-source computed tomography scanner (Somatom Definition, Siemens Medical Systems, Forchheim, Germany). Patients with heart rates ≥70 beats/min and no contraindications (documented allergy, active bronchospastic disease, or systolic blood pressure <100 mm Hg) were administered oral (up to 100 mg) and/or intravenous metoprolol (5 mg injection every 1 to 2 min, up to 30 mg) to attain a heart rate <70 beats/min. Imaging proceeded even if heart rate remained ≥70 beats/min after maximal beta-blockade.

An initial noncontrast coronary calcium scan was performed, with electrocardiographic (ECG) triggering at a heart rate dependent percent of the R-R interval, 350-mm field of view, and a scan protocol of 2.5-mm slice thickness, 120-kVp tube voltage, and 42-mAs tube current. Unless contraindicated, a sublingual spray of 0.4 mg nitroglycerin (Sciele Pharma, Alpharetta, Georgia) was then given, followed by power injection of 92 ml of intravenous contrast (Omnipaque or, if serum creatinine was >1.5 g/dl, Visipaque, GE Healthcare, Princeton, New Jersey) into the antecubital vein at 5 ml/s, chased by 80 ml of saline at 5 ml/s. As soon as ≥100 HU was detected in the ascending aorta, ECG-gated helical scanning was performed from 1 cm below tracheal bifurcation to the diaphragm during a 10-s breath-hold. Scanning parameters included: heart-rate-dependent pitch (range 0.2 to 0.45), 330 ms gantry rotation time, 100 kVp or 120 kVp tube voltage, and 600 mAs tube current. Lower tube voltage (100 kVp) was used in patients with a body mass index (BMI) <30 kg/m^2, weight <85 kg, and absence of dense coronary calcification on the noncontrast scan. The ECG-based dose modulation was used whenever possible to limit radiation dose.

Coronary calcium evaluation. Noncontrast computed tomography images were transferred to a ScImage workstation (Los Altos, California) for measurement of the Agatston coronary calcium score as previously described (11,12).

CTA image reconstruction. Retrospectively gated reconstruction of raw CTA data was routinely performed at 40%, 65%, 70%, 75%, and 80% of the R-R interval using the following parameters: 0.6-mm slice thickness (0.75 mm if BMI >35 kg/m^2), 0.3-mm slice increment, 250-mm field of view, 512 × 512 matrix, and B26f medium smooth kernel. The B46f sharp kernel was also used in patients with coronary stents or coronary calcium score >100. Whenever images from routine reconstruction were significantly degraded because of arrhythmia or motion, reconstruction of additional cardiac phases and/or by manual ECG editing were performed.

CTA image evaluation. Reconstructed data were transferred to a Hewlett-Packard workstation (Palo Alto, California), where coronary analysis was done using the Vitrea 2 software (Vital Images, Minnetonka, Minnesota). Two experienced CTA readers, blinded to patient clinical status and ICA results, visually assessed all coronary segments by evaluating standard axial images, oblique long- and short-axis multiplanar reconstructions, and oblique long- and short-axis maximum intensity projections (13).

A coronary segment was first evaluated for presence of ≥70% luminal diameter obstruction (≥50% if left main coronary artery) by visual inspection (14). This criterion was used for both noncalcified and calcified plaque, as long as the luminal-side

ABBREVIATIONS AND ACRONYMS

ACC = American College of Cardiology

AHA = American Heart Association

ANCOVA = analysis of covariance

BMI = body mass index

CTA = computed tomographic angiography

CT = computed tomography

CTQCA = computed tomography-based quantitative coronary analysis

ECG = electrocardiogram

ICA = invasive coronary angiography

IQCA = invasive angiography-based quantitative coronary analysis

PCI = percutaneous coronary intervention

SPECT-MPI = single-photon emission computed tomography myocardial perfusion imaging

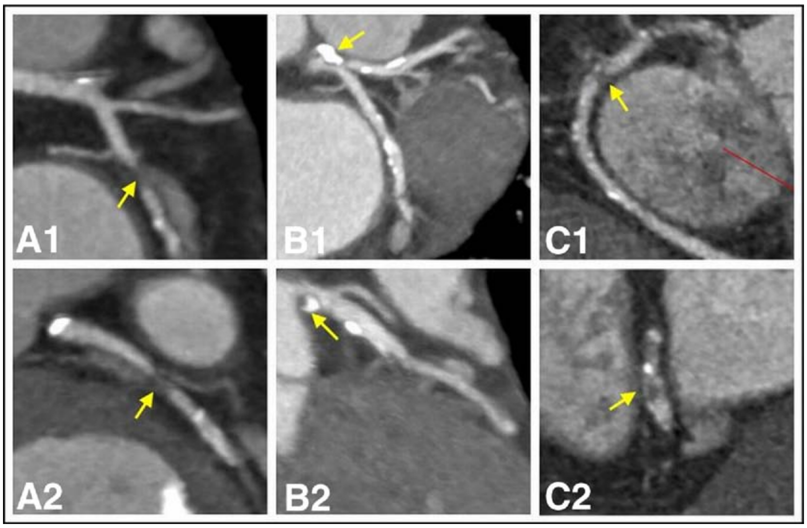

Figure 1. **Examples of ≥70% Diameter Stenoses by Visual Inspection on CTA**

Images were displayed using Vitrea 2 software (Minnetonka, Minnesota). Determination of stenosis severity was based on at least 2 longitudinal views **(top and bottom panels in each column)**. **Yellow arrows** indicate sites of severe stenosis. Left panels **(A1, A2)** show severe, noncalcified focal stenosis of a proximal left circumflex artery. Middle panels **(B1, B2)** show severe, predominantly calcified stenosis of the distal left main coronary artery. This lesion seemed to involve ostia of both the left anterior descending and left circumflex arteries. Right panels **(C1, C2)** show a severe, noncalcified focal stenosis of the mid right coronary artery. CTA = computed tomographic angiography.

plaque edge was clearly visualized. Examples of such stenoses are shown in Figure 1. When a ≥70% stenotic lesion was identified, CTA readers consensually evaluated morphologic characteristics of the lesion by applying current modified American College of Cardiology/American Heart Association (ACC/AHA) morphology criteria (9,10,15). Type C morphology was defined by any of the following findings (Table 1): ostial involvement, major side branch involvement, marked proximal vessel tortuosity, >90° angle at lesion site, >20 mm lesion length, or total occlusion. To obtain lesion length, longitudinal dimension of the responsible plaque was measured in the oblique multiplanar reconstruction view that best showed its entire course (Fig. 2); when multiplanar reconstruction could not display the plaque fully, oblique maximal intensity projection with the smallest necessary thickness was used. The CTA readers also qualitatively graded the degree of plaque calcification (grade 0 = none, 1 = <1/3 calcified plaque contribution to total plaque volume, 2 = 1/3 to 2/3 calcified, 3 = >2/3 calcified). Nondiagnostic segments were considered <70% stenotic.

Table 1. **Modified ACC/AHA Type C Stenosis Morphology Criteria***

Ostial involvement
Crosses major branch
Length >20 mm
Total occlusion
Excessive vessel tortuosity proximal to the lesion
>90° angle at lesion site

*Type C lesions show at least 1 of these morphologies.
ACC/AHA = American College of Cardiology/American Heart Association.

After completing these for each ≥70% stenotic lesion, one reader manually performed computed tomography–based quantitative coronary analysis (CTQCA) using a simplified calculation that estimates linear tapering of the coronary artery based on the initial method described by Reiber et al. (16). The following measurements were made: reference vessel diameter proximal to the stenosis (D_{prox}), reference vessel diameter distal to the stenosis (D_{dis}), luminal diameter at the site of stenosis (D_{sten}), distance between proximal reference site and distal reference site (X_1), and distance between proximal reference site and maximally stenotic site (X_2). Maximal degree of stenosis was then calculated using the following formula:

$$\text{Stenosis (\%)} = [1 - (D_{sten}) / (D_{prox} - [\{X1/X2\} * \{D_{prox} - D_{dis}\}])] \times 100$$

In a separate investigation, we showed that quantitative coronary analysis results generated from this

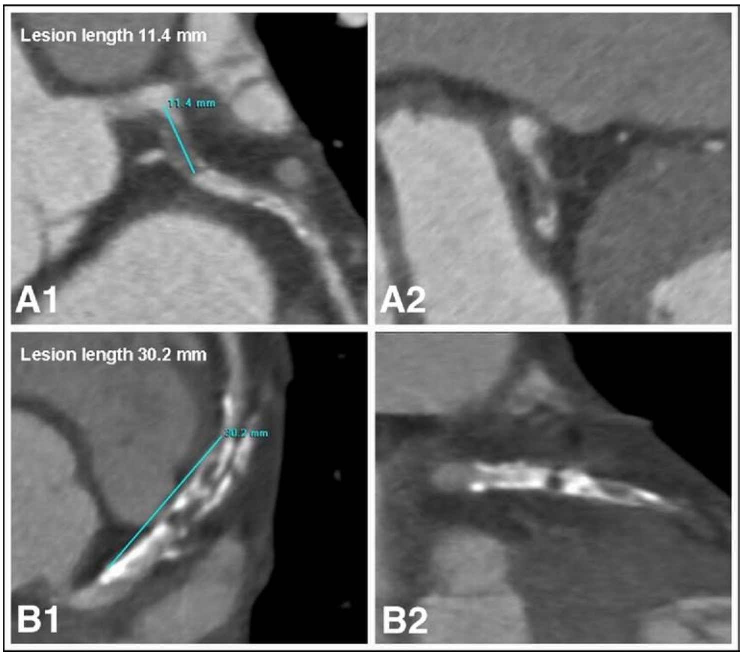

Figure 2. Determining Stenosis Length on CTA

Stenosis length was obtained by measuring plaque dimension in the long-axis oblique multiplanar reconstruction image that best showed the entirety of the plaque. **(A1, A2)** Longitudinal views of severe stenosis from a noncalcified plaque in the proximal left circumflex artery. The plaque measured 11.4 mm in length **(A1)**. **(B1, B2)** Longitudinal views of a severe stenosis in the proximal left anterior artery from a complex plaque with calcified and noncalcified components. Length of this plaque is 30.2 mm, classifying the stenosis as type C. CTA = computed tomographic angiography.

formula were nearly identical to results from the standard, computer-based technique when used on ICA images (14).

ICA image acquisition and procedural information. The ICA was performed using the Inova digital X-ray system from GE Healthcare (Buckinghamshire, United Kingdom). Standard catheterization technique was used. Acquired images were transferred to an AGFA Heartlab workstation (Greenville, South Carolina) for analysis. Catheterization records were reviewed to obtain frequency of PCI, PCI procedure time (defined as the time from insertion to removal of intracoronary guide wire), and amount of contrast used.

ICA image evaluation. An interventional cardiologist and a senior cardiology fellow evaluated all ICA images while being blinded to CTA results, patient clinical status, and whether PCI was actually performed. For each segment, both readers visually inspected available ICA images to consensually determine whether ≥70% luminal narrowing was present. Each identified ≥70% stenosis was subsequently defined as type C or nontype C, based on the same modified ACC/AHA criteria used by CTA readers.

One ICA reader then performed invasive angiography-based quantitative coronary angiography (IQCA) on each ≥70% stenotic lesion. In the most stenotic-appearing projection, the reader defined reference luminal positions proximal and distal to the stenosis. Activation of quantitative coronary analysis software on the Heartlab workstation then detected luminal edges, located site of maximal stenosis, and calculated the corresponding degree of maximal stenosis (16). Whenever automatic edge detection failed, manual luminal tracing was performed in its place.

Statistical methods. Continuous variables are described as means ± SD. Mean PCI time and total contrast use in patients with and without type C lesions were compared using analysis of covariance (ANCOVA) with adjustments for age and BMI (SAS software, version 9, SAS Institute, Cary, North Carolina). Analysis using log-transforms of PCI time and contrast use was also performed to satisfy standard assumptions of ANCOVA. With the exception of ANCOVA analysis, all data were analyzed using Stata version 8 (Stata Corp., College Station, Texas).

JACC: CARDIOVASCULAR IMAGING, VOL. 2, NO. 8, 2009
AUGUST 2009:950–8

Table 2. Study Patient Characteristics (n = 85)

	n	%	Mean ± SD
Age (yrs)			66 ± 11
Body mass index (kg/m²)			27.7 ± 4.6
Men	63	74	
White	62	73	
Previous MI	12	14	
Previous PCI	19	22	
Previous CABG	6	7	
Previous MI, PCI, or CABG	29	34	
Diabetes mellitus	26	31	
Hypertension	53	62	
Cigarette smoking	26	31	
Hypercholesterolemia	60	71	
Family CAD history	33	39	
Current statin therapy	46	54	
Typical angina	31	36	
Atypical angina	26	31	
Dyspnea	18	21	
Asymptomatic	25	29	
Positive SPECT study	22	26	
Heart rate during CTA			59 ± 13
Agatston calcium score			734 ± 873
Number of coronary segments			11 ± 2.5

CABG = coronary artery bypass grafting; CAD = coronary artery disease; CTA = computed tomographic angiography; MI = myocardial infarction; PCI = percutaneous coronary intervention; SD = standard deviation; SPECT = single-photon emission computed tomography.

RESULTS

Clinical characteristics of the 85 study patients are noted in Table 2. Most of the population was male (74%). Mean age, BMI, and Agatston score were 66 years, 27.7 kg/m^2, and 734, respectively. Mean heart rate during CTA acquisition was 59 beats/min (range 39 to 112 beats/min). CTA was performed as follow-up to single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI) in 37 patients (44%); SPECT-MPI was abnormal in 22 patients (26%). Of the 48 patients who did not undergo SPECT-MPI, 34 reported chest pain or dyspnea. In the remaining 14 asymptomatic patients, CTA was performed for pre-operative assessment (n = 7) or pre-clinical disease assessment (n = 7). A total of 940 segments in 328 arteries were evaluated.

Visual inspection of ICA images identified 93 lesions that caused ≥70% stenosis. Calcification severity of these lesions by CTA were grade 3 in 28 (30%), grade 2 in 11 (12%), grade 1 in 21 (23%), and none in 33 (35%). IQCA was successful in 90 cases; 3 cases could not be quantified because of lack of orthogonal images. Median stenosis by IQCA was 73.3%, with ≥70% stenosis in 55 lesions (61%) and ≥60% stenosis in 79 lesions (88%).

Visual inspection of CTA images identified 101 lesions that caused ≥70% stenosis. CTQCA was successful in all cases. Median stenosis by CTQCA was 77.3%, with ≥70% stenosis in 69 lesions (68%) and ≥60% stenosis in 95 lesions (94%).

CTA determination of ≥70% stenotic type C lesions. CTA detected 84 of 93 lesions (90%) that caused ≥70% stenosis on ICA, and 49 of 52 patients (94%) found to have at least 1 such lesion on ICA. CTA falsely identified ≥70% stenotic lesions in 17 segments and 8 patients. Table 3 shows the distribution of these lesions in the principal coronary artery territories.

Of the 93 ≥70% stenotic lesions on ICA, 53 (57%) were type C; CTA correctly characterized presence of type C morphology in 42 of these lesions (79%) and detected 31 of 35 patients (89%) found to have at least 1 ≥70% stenotic lesion with type C morphology. Eight patients had stenoses fulfilling multiple type C criteria, and CTA correctly identified at least 1 feature in 7 of these patients. False-positive type C morphology by CTA occurred in 7 segments and 3 patients. Examples of type C lesions on ICA and CTA are shown in Figure 3.

Table 3. Detection of ≥70% Stenosis by Visual CTA and ICA Evaluation

	≥70% Stenotic on ICA	Correctly Identified on CTA (%)	Not Identified on CTA (%)	False Positive on CTA (%)
Total	93	84 (90)	9 (10)	17 (17)
Left main*	8	8 (100)	0 (0)	1 (11)
LAD territory	37	33 (89)	4 (11)	10 (23)
LCX territory	23	19 (83)	4 (17)	1 (5)
RCA territory	25	24 (96)	1 (4)	5 (17)

*For left main, threshold was ≥50% stenosis.
ICA = invasive coronary angiography; LAD = left anterior descending artery; LCX = left circumflex artery; RCA = right coronary artery; other abbreviations as in Table 2.

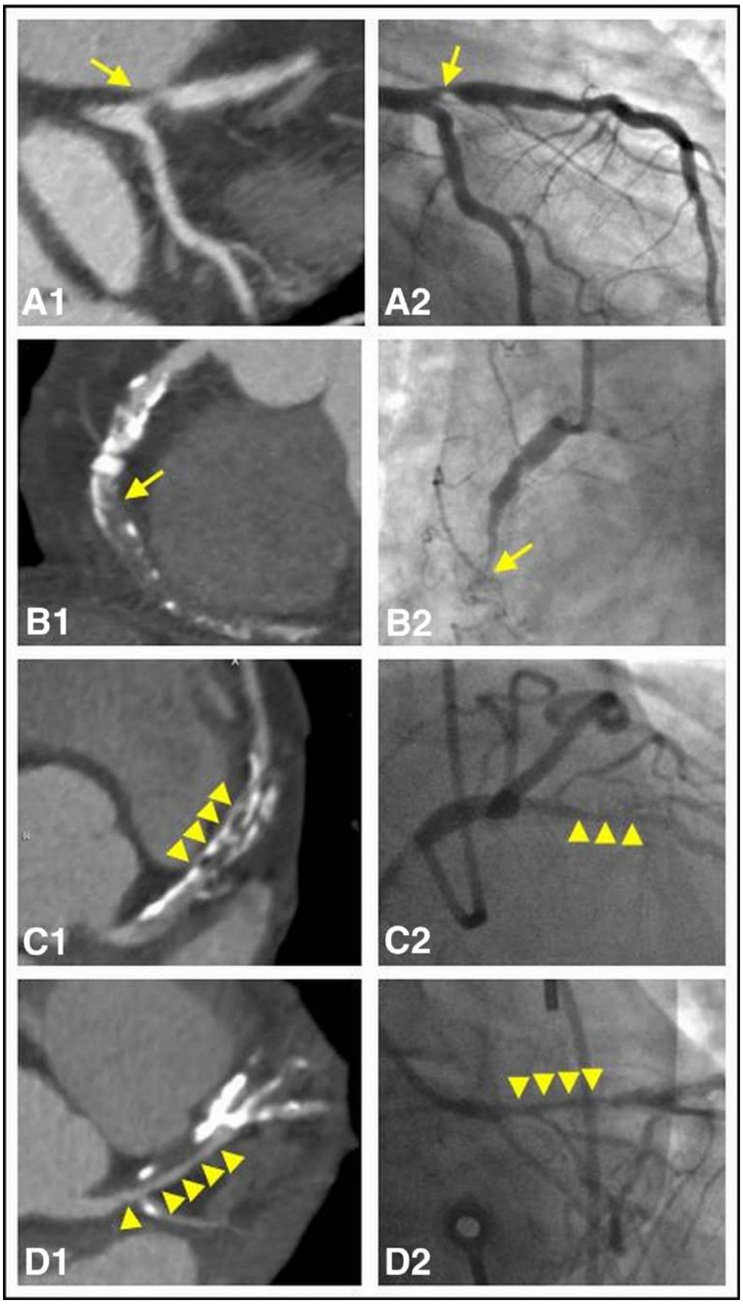

Figure 3. Representative Type C Lesions Identified by CTA and ICA

The CTA images are on the left; the ICA images are on the right. **(A1, A2)** Ostial involvement: **yellow arrows** indicate ostial stenosis of the left anterior descending artery. **(B1, B2)** Total occlusion: a long, predominantly noncalcified plaque in the mid right coronary artery is accompanied by absence of luminal contrast, indicating a total occlusion (**yellow arrows**), confirmed on ICA. **(C1, C2)** Long lesion (also shown in Fig. 2): a long region in the proximal left anterior descending artery appeared severely stenotic from calcified and noncalcified plaque on CTA. Length of this region measured >20 mm on ICA (**yellow arrowheads**), meeting type C criterion. **(D1, D2)** Major branch involvement: a large, predominantly noncalcified plaque extending from the left main artery into the left anterior descending artery causes severe stenosis in both vessels while crossing the left circumflex artery. Branch involvement and >20 mm lesion length were confirmed on ICA (**yellow arrowheads**). CTA = computed tomographic angiography; ICA = invasive coronary angiography.

JACC: CARDIOVASCULAR IMAGING, VOL. 2, NO. 8, 2009
AUGUST 2009:950–8

Table 4. **Correct and Incorrect Characterization of Type C Lesions by CTA**

	n (on ICA)	Correctly Identified on CTA (%)	Not Identified on CTA (%)	False Positive on CTA (%)
Total	62	46 (74)	16 (26)	22 (32)
Ostial	20	15 (75)	5 (25)	2 (12)
Crosses major branch	15	13 (93)	2 (7)	12 (48)
Total occlusion	9	7 (78)	2 (22)	3 (30)
>20 mm in length	18	11 (61)	7 (39)	4 (26)
Proximal vessel tortuosity	0	0 (0)	0 (0)	1 (100)
>90° angle at lesion	0	0 (0)	0 (0)	0 (0)

Abbreviations as in Tables 2 and 3.

Detection of specific type C morphologies is shown in Table 4. CTA correctly characterized 46 of 62 distinct type C features (74%; 7 lesions showed 2 type C features, and 1 showed 3). The most frequent false positive type C morphology on CTA was branch involvement (12 cases); the most frequent miss was lesion length >20 mm (7 cases). ICA found no cases of excessive proximal vessel tortuosity or >90° angle at stenosis site.

Type C morphology on CTA and PCI procedure duration and contrast use. PCI was performed in 36 patients for 46 lesions. In 14 of these patients, PCI was performed on 14 type C lesions (1 per patient; 7 were ostial, 2 crossed a major branch, 3 had length >20 mm, and 2 had length >20 mm and crossed a major branch). Frequency of multiple-lesion PCI and number of lesions that underwent PCI per patient were similar in patients with and without a type C lesion (21% vs. 23% and 1.29 vs. 1.27, respectively). No PCI was attempted for a total occlusion. Procedure time was available in 34 of these patients, and total amount of contrast used was available in 31. Presence of a type C lesion on CTA was independently associated with significantly longer procedure duration (42 ± 25 min vs. 21 ± 13 min, $p = 0.009$) and greater contrast use (263 ± 150 ml vs. 140 ± 47 ml, $p = 0.001$) when controlling for age and BMI. These results were confirmed with log-transform analysis and are summarized in Table 5.

DISCUSSION

We conducted a systematic, blinded, expert evaluation of CTA and ICA to assess the utility of CTA in determining complex stenosis morphology before ICA. Two principal findings emerged from our study. One, in native coronary arterial segments ≥2 mm in diameter, CTA can detect severely stenotic lesions with complex morphologies as defined by the modified ACC/AHA type C criteria. Two, identification of a ≥70% stenosis with type C morphology on CTA predicts longer procedure times and higher contrast use during PCI. In our study design, ≥70% diameter stenosis on CTA must be present before assessment of type C morphology. We believe this stepwise approach emulates the setting of real-life ICA, in which angiographers often triage lesion significance by visual impression of stenosis severity. Lesions causing ≥70% stenosis draw stronger consideration for intervention, evidenced by its adoption as primary angiographic criterion for revascularization in several landmark clinical trials (17–20). Greater attention is then paid to stenosis morphology as the angiographer begins to plan technical approaches

Table 5. **Mean PCI Time and Contrast Use in Patients With and Without a Type C Lesion on ICA and CTA**

	With No Type C	With Type C	p Value*
ICA			
Mean PCI time (min)	21.6 ± 12.8	43.7 ± 25.2	0.005 (0.003)†
Mean contrast use (ml)	137.1 ± 39.2	275.1 ± 152.3	0.003 (0.01)†
CTA			
Mean PCI time (min)	21.5 ± 13.3	42.4 ± 24.7	0.009 (0.003)†
Mean contrast use (ml)	139.7 ± 47.4	262.6 ± 150.0	0.001 (0.02)†

*Adjusted for age and body mass index. †p Values obtained after log-transforming PCI time and contrast use.
Abbreviations as in Tables 2 and 3.

for PCI. Our data showed that CTA can identify stenoses severe enough to prompt closer inspection of morphology during ICA and has the additional value of identifying specific type C morphologic features.

Characterizing complex stenosis morphology on CTA can be a challenging task. In our study, CTA failed to detect 16 of 62 (26%) type C features. The most commonly missed type C features were ostial involvement (5 cases) and lesion length >20 mm (7 cases). Although some underestimation of true lesion length by standard oblique displays of CTA data was expected, why CTA also overlooked certain ostial lesions is unclear. Perhaps concern regarding coronary instrumentation and eventual stent selection increased ICA reader tendency to characterize ostial involvement in borderline cases. The most frequent false positive type C feature on CTA was major side branch involvement (12 cases). Limitations in CTA spatial resolution may have caused visual impression of greater plaque extent in comparison to that seen on ICA. It is also possible that ICA may have underestimated lesion complexity in some cases.

Despite the high coronary calcium scores (mean of 734) in our population, 35% of ≥70% stenoses were caused by noncalcified lesions. Two factors likely contributed to this unusual finding. One, referring clinicians probably pursued ICA more frequently when CTA reported ≥70% stenosis from noncalcified plaque than from calcified plaque, inflating the number of severely stenotic noncalcified lesions. Two, perhaps the presence of stenotic noncalcified plaque in patients with a high coronary calcium score is associated with clinical findings suggesting worsening of coronary disease status, prompting referral to CTA.

Our study adds information to the limited literature regarding the ability of CTA to identify complex lesion morphology (21–24), which has primarily focused on total occlusions. Two groups used 16-slice CTA to evaluate plaque characteristics of known chronic total occlusions (21,23), and Mollet et al. (24) found that severe calcification and lesion length >15 mm on 16-slice CTA was associated with procedural failure when attempting recanalization of a chronic total occlusion. In a separate publication, conventional 64-slice CTA showed promising results in characterizing ostial, bifurcation, and totally occluded lesions; however, morphologic characteristics could not be assessed in 15% of known lesions, primarily because of motion artifact (22). By strictly applying accepted ACC/AHA definitions of complex lesion morphology and retaining nondiagnostic segments in our analysis, we systematically showed that CTA can alert clinicians to the presence of severe stenoses that are long, are totally occluded, involve vessel ostia, or cross major side branches.

To the best of our knowledge, this is the first study to show an association of type C lesions on CTA with increases in 2 clinically relevant PCI procedural parameters: procedure length and contrast use. Clinical implications of these associations are 2-fold. First, the patient with risk factors for renal insufficiency and type C lesions on CTA should be considered at higher risk for contrast-induced nephropathy before planned PCI. Second, the interventional cardiologist can be provided with a priori knowledge of lesion complexity. Identification of a severely stenotic lesion with type C morphology on CTA is a strong indicator of increased difficulty with percutaneous revascularization.

Study limitations. This was a single-center retrospective study of modest size. A significant portion of study patients manifested severe coronary disease before CTA, and referring clinicians at our institution likely proceeded with invasive angiography far more frequently when ≥70% stenosis was found on CTA; both of these factors probably contributed to the high prevalence of severely obstructive lesions (61% of patients). Excessive tortuosity proximal to the lesion and highly angular lesions were not represented. Because consensual expert reading of CTA is not routine in community practice, reported results may be more impressive than that seen in community imaging centers. Our decision to use visual assessment as a primary criterion for determining stenosis severity on ICA was chosen to reflect common clinical practice; however, there is a known propensity of visual assessment to overestimate the severity of lesions on invasive angiography, confirmed by our stenosis quantification calculations.

CONCLUSIONS

By using a visual cutoff of ≥70% diameter stenosis in vessels segments ≥2 mm in diameter, CTA can predict lesions likely to reach ≥70% stenosis on ICA and provide added value in discerning complex lesion morphologies associated with these lesions. Moreover, the presence of complex, severely obstructive lesions on CTA predicts greater contrast use and longer procedure duration during PCI. Because this information can be important to the referring noninvasive and interventional cardiologists, we recommend that CTA readers routinely describe the morphology of each detected severe stenosis. Whether PCI planning with CTA provides true clinical benefit will require investigation in a systematic prospective trial.

Reprint requests and correspondence: Dr. Daniel S. Berman, 8700 Beverly Boulevard, Taper Building Room 1258, Los Angeles, California 90048. *E-mail: daniel.berman@cshs.org.*

REFERENCES

1. Leschka S, Alkadhi H, Plass A, et al. Accuracy of MSCT coronary angiography with 64-slice technology: first experience. Eur Heart J 2005;26:1482–7.
2. Raff GJ, Gallagher MJ, O'Neill WW, Goldstein JA. Diagnostic accuracy of noninvasive angiography using 64-slice spiral computed tomography. J Am Coll Cardiol 2005;46:552–7.
3. Mollet NR, Cademartiri F, van Mieghem CA, et al. High-resolution spiral computed tomography coronary angiography in patients referred for diagnostic conventional coronary angiography. Circulation 2005;112:2318–23.
4. Fine JJ, Hopkins CB, Ruff N, Newton FC. Comparison of accuracy of 64-slice cardiovascular computed tomography with coronary angiography in patients with suspected coronary artery disease. Am J Cardiol 2006;97:173–4.
5. Hamon Mi, Biondi-Zoccai G, Malagutti P, et al. Diagnostic performance of multislice spiral computed tomography of coronary arteries as compared with conventional invasive coronary angiography: a meta-analysis. J Am Coll Cardiol 2006;48:1896–910.
6. Abdulla J, Abildstrom SZ, Gotzsche O, Christensen E, Kober L, Torp-Pedersen C. 64-multislice detector computed tomography coronary angiography as potential alternative to conventional coronary angiography: a systematic review and meta-analysis. Eur Heart J 2007;28:3042–50.
7. Miller JM, Rochitte CE, Dewey M, et al. Diagnostic performance of coronary angiography by 64-row CT. N Engl J Med 2008;359:2324–36.
8. Budoff MJ, Dowe D, Jollis JG, et al. Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. J Am Coll Cardiol 2008;52:1724–32.
9. Ellis SG, Vandormael MG, Cowley MJ, et al. Coronary morphologic and clinical determinants of procedural outcome with angioplasty for multivessel coronary disease: implications for patient selection. Circulation 1990;82:1193–202.
10. Ellis SG, De Cesare NB, Pinkerton CA, et al. Relation of stenosis morphology and clinical presentation to the procedural results of directional coronary atherectomy. Circulation 1991;84:644–53.
11. Agatston AS, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. J Am Coll Cardiol 1990;15:827–32.
12. Berman DS, Wong ND, Gransar H, et al. Relationship between stress-induced myocardial ischemia and atherosclerosis measured by coronary calcium tomography. J Am Coll Cardiol 2004;44:923–30.
13. Ferencik M, Ropers D, Abbara S, et al. Diagnostic accuracy of image postprocessing methods for the detection of coronary artery stenoses by using multidetector CT. Radiology 2007;243:696–702.
14. Cheng VY, Gutstein A, Wolak A, et al. Moving beyond binary grading of coronary arterial stenoses on coronary CT angiography: insights for the imager and referring physician. J Am Coll Cardiol Img 2008;1:460–71.
15. Ryan TJ, Bauman WB, Kennedy JW, et al. Guidelines for percutaneous transluminal coronary angioplasty: a report of the ACC/AHA Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures. J Am Coll Cardiol 1993;22:2033–54.
16. Reiber JHC, Serruys PW, Kooijman CJ, et al. Assessment of short-, medium, and long-term variations in arterial dimensions from computer assisted quantitation of coronary cineangiograms. Circulation 1985;71:280–8.
17. The RITA-2 trial participants. Coronary angioplasty versus medical therapy for angina: the Second Randomised Intervention Treatment of Angina (RITA-2) trial. Lancet 1997;350:461–8.
18. Hueb W, Soares PR, Gersh BJ, et al. The Medicine, Angioplasty, or Surgery Study (MASS-II): a randomized, controlled clinical trial of three therapeutic strategies for multivessel coronary artery disease: one-year results. J Am Coll Cardiol 2004;43:1743–51.
19. McFalls EO, Ward HB, Moritz TE, et al. Coronary-artery revascularization before elective major vascular surgery. N Engl J Med 2004;351:2795–804.
20. Boden WE, O'Rourke RA, Teo KK, et al., for the COURAGE Trial Research Group. Optimal medical therapy with or without PCI for stable coronary disease. N Engl J Med 2007;356:1503–16.
21. Yokoyama N, Yamamoto Y, Suzuki S, et al. Impact of 16-slice computed tomography in percutaneous coronary intervention of chronic total occlusions. Catheter Cardiovasc Interv 200;68:1–7.
22. Sheth TN, Rieber J, Mooyaart EA, et al. Usefulness of coronary computed tomographic angiography to assess suitability for revascularization in patients with significant coronary artery disease and angina pectoris. Am J Cardiol 2006;98:1198–201.
23. Soon KH, Cox N, Wong A, et al. CT coronary angiography predicts the outcome of percutaneous coronary intervention of chronic total occlusion. J Interv Cardiol 2007;20:359–66.
24. Mollet NR, Hoye A, Lemos PA, et al. Value of preprocedure multislice computed tomographic coronary angiography to predict the outcome of percutaneous recanalization of chronic total occlusions. Am J Cardiol 2005;95:240–3.

Key Words: computed tomography ■ coronary angiography ■ revascularization ■ percutaneous coronary intervention.

▶APPENDIX

For an additional supplement, "Characterization of Complex Coronary Artery Stenosis Morphology by Coronary Computed Tomographic Angiography," please see the online version of this article.