Predictors of Inaccurate Coronary Arterial Stenosis Assessment by CT Angiography

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OBJECTIVES This study sought to investigate the clinical and imaging characteristics associated with diagnostic inaccuracy of computed tomography angiography (CTA) for detecting obstructive coronary artery disease (CAD) defined by quantitative coronary angiography (QCA).

BACKGROUND Although diagnostic performance metrics of CTA have been reported, there are sparse data on predictors of diagnostic inaccuracy by CTA.

METHODS The clinical characteristics of 291 patients (mean age: 59 ± 10 years; female: 25.8%) enrolled in the multicenter Core-64 (Coronary Artery Evaluation Using 64-Row Multi-detector Computed Tomography Angiography) study were examined. Pre-defined CTA segment-level characteristics of all true-positive (N = 237), false-positive (N = 115), false-negative (FN) (N = 159), and a random subset of true-negative segments (N = 511) for ≥50% stenosis with QCA as the reference standard were blindly abstracted in a central core laboratory. Factors independently associated with corresponding levels of CTA diagnostic inaccuracies on a patient level and coronary artery segment level were determined using multivariable logistic regression models and generalized estimating equations, respectively.

RESULTS An Agatston calcium score of ≥1 per patient (odds ratio [OR]: 5.2; 95% confidence interval [CI]: 1.1 to 24.6) and the presence of within-segment calcification (OR: 10.2; 95% CI: 5.2 to 19.8) predicted false-positive diagnoses. Conversely, absence of within-segment calcification was an independent predictor of an FN diagnosis (OR: 2.0; 95% CI: 1.2 to 3.5). Prior percutaneous revascularization was independently associated with patient-level misdiagnosis of obstructive CAD (OR: 4.2; 95% CI: 1.6 to 11.2). Specific segment characteristics on CTA, notably segment tortuosity (OR: 3.5; 95% CI: 2.4 to 5.1), smaller luminal caliber (OR: 0.48; 95% CI: 0.36 to 0.63 per 1-mm increment), and juxta-arterial vein conspicuity (OR: 2.1; 95% CI: 1.4 to 3.2), were independently associated with segment-level misdiagnoses. Attaining greater intraluminal contrast enhancement independently lowered the risk of an FN diagnosis (OR: 0.96; 95% CI: 0.94 to 0.99 per 10-Hounsfield unit increment).

CONCLUSIONS We identified clinical and readily discernible imaging characteristics on CTA predicting inaccurate CTA diagnosis of obstructive CAD defined by QCA. Knowledge and appropriate considerations of these features may improve the diagnostic accuracy in clinical CTA interpretation. (Diagnostic Accuracy of Multi-Detector Spiral Computed Tomography Angiography Using 64 Detectors [CORE-64]; NCT00738218) (J Am Coll Cardiol Img 2013;6:963–72) © 2013 by the American College of Cardiology Foundation
Delineating the presence and anatomic extent of obstructive coronary artery disease (CAD) provides vital prognostic information and guides the management of patients with ischemic heart disease (1–4). Accumulating evidence from single-center and multicenter studies has demonstrated high accuracy of contemporary computed tomography angiography (CTA) for the diagnosis of obstructive CAD (5–8). Accordingly, CTA has been included in recent American and European recommendations as a valuable noninvasive alternative in the diagnostic evaluation of patients at low-to-intermediate probability for CAD (9,10).

Although numerous factors affect the comparison between CTA and invasive quantitative coronary angiography (QCA) (11), there is a paucity of data on how clinical and CTA imaging characteristics influence the diagnostic accuracy of CTA. Accordingly, the objective of this study is to examine patient clinical and coronary arterial segment characteristics on CTA associated with inaccurate diagnosis of obstructive CAD as defined by QCA.

METHODS

Study design and population. The CorE-64 (Coronary Artery Evaluation Using 64-Row Multi-detector Computed Tomography Angiography) study is a prospective, multicenter investigation to examine the diagnostic accuracy of CTA to detect CAD in comparison with QCA (12). Its study design and primary results have been reported (7,12). Briefly, patients aged ≥40 years who were referred for clinically indicated invasive coronary angiography were recruited from 9 international centers. Exclusion criteria included prior cardiac surgery, percutaneous coronary intervention within the past 6 months, history of iodinated contrast allergy, history of or high-risk features for contrast-induced nephropathy, tachyarrhythmia or second/third-degree atrioventricular block, advanced heart failure or aortic stenosis, body mass index >40 kg/m², and contraindications to beta-blocker. Patients with an Agatston score >600 were pre-specified to be excluded from the primary analysis. The study was approved by the local institutional review board of all participating centers. All patients provided written informed consent.

Invasive coronary angiography acquisition and analysis. Clinically indicated invasive angiography was performed within 30 days after CTA using standardized angiographic techniques. Images were forwarded to the QCA core laboratory for centralized blinded analysis. The coronary tree was segmented and analyzed according to a modified 19-segment model (7,12,13). All nonstented coronary segments ≥1.5 mm in diameter were visually assessed for ≥30% stenoses that were quantified by QCA (CASS-II, QCA, version 2.0.1, PIE Medical Imaging, Maastricht, the Netherlands). The most severe stenosis was determined within each segment and for each patient. Significant obstructive CAD was defined on QCA as luminal diameter narrowing of ≥50%.

CTA acquisition and post-processing. All images were acquired using a commercially available computed tomography scanner (Aquilion 64, Toshiba Medical Systems, Tochigi, Japan). Noncontrast imaging was performed using prospective electrocardiogram gating for Agatston calcium scoring. CTA was completed with retrospective electrocardiogram gating. Beta-blockers were administered in compliance with local institutional standards at each center when the resting heart rate was >70 beats/min to achieve a target heart rate of <70 beats/min. Sublingual nitroglycerine was routinely administered.

ABBREVIATIONS AND ACRONYMS

BMI = body mass index
CAD = coronary artery disease
CI = confidence interval
CTA = computed tomography angiography
FN = false-negative
FP = false-positive
OR = odds ratio
QCA = quantitative coronary angiography
TN = true-negative
TP = true-positive

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prescribed along with weight-based intravenous administration of iopamidol (Isovue 370, Bracco Diagnostics, Inc., Monroe Township, New Jersey) at 3.5 to 5.0 ml/s before image acquisition as triggered by bolus tracking during a single 12- to 14-s breath-hold.

Raw data were transferred to the CTA core laboratory for post-processing and blinded interpretation per standardized protocols (7,12). Images were reconstructed at 0.5-mm slice thickness with 0.3-mm overlap. Multiple systolic and diastolic phases with the least cardiac motion were routinely reconstructed with standard (FC43) and as appropriate additional sharper (FC05) kernels. Optimal reconstruction was identified for each vessel from which it was segmented and labeled in accordance with the modified 19-segment model for cross-comparison with QCA (12,13).

**CTA stenosis interpretation.** Two independent CTA readers visually graded each nonstenated segment for stenosis according to an ordinal scale (12). All segments with visible luminal narrowing of ≥30% were quantified for maximum percentage luminal diameter stenosis by a semiautomatic contour detection algorithm using commercially available software (Vitrea Version 3.9.0.1, Vital Images, Minnetonka, Minnesota). Segments deemed non-evaluable or with inter-reader visual and/or quantitative stenosis discrepancies crossing the 50% evaluable or with inter-reader visual and/or quantitative stenosis discrepancies crossing the 50% threshold underwent consensus grading incorporating a third experienced observer. After finalization of all qualitative and quantitative segmental stenosis measurements independently by both QCA and CTA core laboratories for the entire trial cohort, an adjudication process was performed to ensure correct cross-modality correspondence of features examined included: 1) segment image quality (good = absence of motion or other artifacts, adequate = assessable with minor motion artifacts, poor = assessable with substantial motion/other artifacts, and non-evaluable); 2) segmental-arterial calcification (none/presence); 3) tortuosity (segment assuming ≥1 within-segment arc(s) of visually estimated ≥60° on multiplanar and/or maximum-intensity projections); 4) vein crossing (cardiac venous structure(s) visualized as crossing or contacting with arterial segment on maximum-intensity projections of ≤2.5-mm slab thickness); 5) segment reference diameter (most proximal disease-free portion of segment determined by semiautomatic contour detection algorithm with manual contour editing); and 6) segment-specific luminal contrast attenuation (mean Hounsfield units of cross-sectional region of interest excluding wall/plaque/calcification at proximal disease-free portion of segment). All post hoc segmental characteristics were abstracted from restored multiplanar reformations, maximum-intensity projections, and cross-sectional images as used for original stenosis assessment. Reference to adjudicated segmentation
Patient-level factors in relation to patient-level CTA diagnostic inaccuracy. Overall, patients with an inaccurate diagnosis of obstructive CAD by CTA were more likely to have known CAD with prior myocardial infarction (32.4% vs. 17.7%, \( p = 0.035 \)) and/or percutaneous coronary intervention(s) (27.0% vs. 7.1%, \( p = 0.001 \)). Specifically, patients with an FN diagnosis more frequently had previous myocardial infarction (45.8% vs. 25.2%, \( p = 0.038 \)) and percutaneous intervention(s) (33.3% vs. 10.1%, \( p = 0.006 \)). Although patients with an accurate diagnosis versus a misdiagnosis had similar Agatston scores (85 vs. 56, \( p = 0.89 \)), there was a heterogeneous relationship between coronary calcification burden and patient-level inaccuracy. Individuals with a TN diagnosis versus an FP diagnosis had lower coronary calcification burden (Agatston score: 1 vs. 49, \( p = 0.047 \)). Conversely, patients with a TP diagnosis versus an FN diagnosis had greater calcium scores: 172 vs. 57 (\( p = 0.035 \)). No other patient-level characteristic was significantly associated with CTA diagnostic inaccuracy. The clinical characteristics, acquisition parameters, and patient-level findings of CTA examination related to the different patient-level inaccuracies are presented in Online Appendix 1.

Independent association between patient-level factors and CTA diagnostic inaccuracy. In multivariable analyses, previous percutaneous coronary intervention was the only patient-level characteristic independently associated with patient-level misdiagnosis, even while considering only nonstented coronary arterial segments (odds ratio [OR]: 4.18; 95% confidence interval [CI]: 1.56 to 11.22). A history of percutaneous coronary intervention(s) was independently associated with patient-level FN diagnosis (OR: 4.29; 95% CI: 1.33 to 13.79), whereas the presence and greater extent of coronary artery calcification independently conferred a lower likelihood of an FN diagnosis (OR: 0.96; 95% CI: 0.93 to 0.99 per 10-U Agatston score increment). The presence of coronary calcification (positive Agatston score) was the only patient-level feature independently associated with an FP diagnosis (OR: 5.22; 95% CI: 1.11 to 24.61; referent: zero Agatston score). These findings were consistent in a series of sensitivity analyses incorporating additional adjustment for previously observed correlates with image quality (14), including body mass index (BMI), heart rate (mean and variability) during image acquisition, and presence of breathing artifact (data not shown).

Segment characteristics on CTA in relation to segment-level CTA diagnostic inaccuracy. The proportional distribution across major coronary vessels of the random TN segment samples examined and the remaining nonselected TN samples in the entire trial cohort was not different (\( p > 0.05 \) for differences) (Online Appendix 2). The characteristics on CTA examination of all segments with TP, FP, and FN diagnoses, and the random subset of TN segment samples examined are summarized in Table 1. Compared with correctly diagnosed segments, misdiagnosed segments were less likely to reside in the left main artery and more likely to reside in the diagonal branches (Table 1a). Of all segments harboring obstructive CAD, those with an FN diagnosis were disproportionally more frequent.
in the diagonal and obtuse marginal/left postero-
lateral branch or ramus intermedius, but less often
in the left anterior descending artery (Table 1b).
Among segments without significant disease, FP
segments were more likely in the left anterior
descending artery and less likely in the posterior
descending/posterolateral branches of the right
coronary artery (Table 1c).

The angiographic appearances of segments on
CTA stratified by diagnostic accuracy (a) overall
among all segments and within subgroups exclu-
sively (b) with and (c) without signi-
cfications as observed with overall misdiagnosis
( )

CTA segment-level characteristics independently pre-
dictive of CTA segment-level diagnostic inaccuracy.
The independent association between segment
characteristics on CTA and segment-level diag-
nostic inaccuracy is presented in Table 2. Segment
tortuosity, cardiac vein over-crossing, and smaller
luminal diameter each independently conferred
increased odds for CTA misdiagnosis (Table 2a),
and specifically FN diagnosis (Table 2b) and
FP diagnosis (Table 2c). Furthermore, greater

### Table 1. Segment Characteristics on CTA According to Segment-Level Diagnostic Concordance Between CTA and QCA for All Studied Segments, Segments With Obstructive CAD on QCA, and Segments Without Obstructive CAD on QCA

<table>
<thead>
<tr>
<th>Segment location</th>
<th>Diagnostic Accuracy (N = 511)</th>
<th>Diagnostic Inaccuracy (N = 115)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left main artery</td>
<td>Diagnostic Concordance (TP)</td>
<td>Diagnostic Discordance (FP)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(N = 237)</td>
<td>(N = 51)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TP (N = 159)</td>
<td>FN (N = 274)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(N = 748)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>187 (25.0)</td>
<td>71 (25.9)</td>
<td>0.11</td>
</tr>
<tr>
<td>Diagonal branches</td>
<td>70 (9.4)</td>
<td>46 (16.8)</td>
<td>0.001</td>
</tr>
<tr>
<td>RCA</td>
<td>145 (19.4)</td>
<td>52 (19.0)</td>
<td>0.89</td>
</tr>
<tr>
<td>PDA/PLV</td>
<td>82 (11.0)</td>
<td>19 (6.9)</td>
<td>0.081</td>
</tr>
<tr>
<td>LCx</td>
<td>109 (14.6)</td>
<td>29 (10.6)</td>
<td>0.001</td>
</tr>
<tr>
<td>OM/ramus intermedius/</td>
<td>124 (16.6)</td>
<td>54 (19.7)</td>
<td>0.001</td>
</tr>
<tr>
<td>left PLV</td>
<td></td>
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</tr>
</tbody>
</table>

| Tomographic segment       | Diagnostic Concordance (CTA Accuracy) | Diagnostic Discordance (CTA Inaccuracy) | p Value* |
| characteristics           | (TP and TN) | (FP and FN) |          |
|                           | (N = 237) | (N = 51) |          |
|                           | (N = 748) | (N = 274) |          |
| Segment tortuosity        | 111 (14.9) | 102 (37.5) | <0.001 |
| Vein crossing             | 127 (17.0) | 79 (29.0) | <0.001 |
| Motion artifact–related   | 445 (59.5) | 207 (75.5) | <0.001 |
| suboptimal segment image  | 294 (39.8) | 164 (61.2) | <0.001 |
| Presence of segmental     | 294 (39.8) | 164 (61.2) | <0.001 |
| coronary calcification    | 294 (39.8) | 164 (61.2) | <0.001 |
| Segment diameter, mm      | 2.71 ± 0.04 | 2.33 ± 0.04 | <0.001 |
| Mean segment luminal       | 441 ± 8 | 424 ± 10 | 0.093 |
| opacification, HU          | 441 ± 8 | 424 ± 10 | 0.093 |

Values are counts (%) or mean ± SE. *Unadjusted complex sample analysis accounted for within-patient clustering.
CAD = coronary artery disease; CTA = computed tomography angiography; FN = false-negative; FP = false-positive; HU = Hounsfield units; LAD = left anterior descending artery; LCx = left circumflex coronary artery; OM = obtuse marginal branches; PDA = posterior descending artery; PLV = posterolateral ventricular branch; QCA = quantitative coronary angiography; RCA = right coronary artery; TN = true-negative; TP = true-positive.
luminal contrast enhancement was independently associated with a lower likelihood for under-
recognizing within-segment stenosis (FN diagnosis) (Table 2b). Although the presence of
calcification independently increased the odds for overall misdiagnosis (OR: 2.49; 95% CI: 1.73 to
3.58) and specifically more significantly FP diagnosis (OR: 10.16; 95% CI: 5.23 to 19.77) (Fig. 1), it
conferred reduced odds for FN diagnosis (OR: 0.50; 95% CI: 0.29 to 0.86). Conversely, obstructive
disease in a segment without calcification, as in noncalcified atherosclerotic plaque, is more likely to
be missed, compared with obstructive disease with calcification in segment, independently of other
segment characteristics (OR: 2.01; 95% CI: 1.17 to 3.46).

After accounting for segment intrinsic characteristics on CTA, segment location per major vessel
categories within the coronary tree was no longer found to be associated with segment-level diag-
nostic inaccuracy (Table 2). Furthermore, patient-level parameters correlating with patient-level
diagnostic performance as observed in this study (e.g., history of CAD) or conceivably image quality
(BMI, heart rate, breathing, or ectopy during acquisition) when added to the models were not
found to affect the segment-level results or to be associated with segment-level diagnostic inaccuracy
(data not shown).

**DISCUSSION**

Although the diagnostic accuracy of CTA for detecting CAD has been extensively delineated, few
data are available addressing factors predicting its diagnostic inaccuracy (15–18). Existing data in this
regard were derived from single-center experiences on modest patient and segment samples of which
characteristics were qualitatively determined without case-control comparisons (15–18). To the best of
our knowledge, this is the first study to report patient clinical and coronary arterial segment charac-
teristics on CTA that are independently associated with the different specific CTA inaccuracies on
both per-patient and per-segment levels.

Lower patient-level diagnostic accuracy for CTA has been reported in obese patients and patients
with poor heart-rate control resulting from images with low signal-to-noise ratio and motion artifacts
(8,14,18–22). However, consistent with our prior investigation on this topic (14), we found that
neither BMI nor heart rate is an independent predictor of patient-level diagnostic inaccuracy. A
potential explanation for this counterintuitive

<table>
<thead>
<tr>
<th>Segment location</th>
<th>(a) Overall Misdiagnosis</th>
<th>(b) FN Diagnosis</th>
<th>(c) FP Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR* (95% CI) p Value</td>
<td>OR* (95% CI) p Value</td>
<td>OR* (95% CI) p Value</td>
</tr>
<tr>
<td>LAD artery</td>
<td>1.02 (0.27–3.83) 0.97</td>
<td>0.14 (0.008–2.390) 0.17</td>
<td>2.59 (0.45–14.71) 0.28</td>
</tr>
<tr>
<td>Diagonal branches</td>
<td>1.06 (0.26–4.40) 0.94</td>
<td>0.22 (0.01–4.37) 0.32</td>
<td>1.52 (0.20–11.67) 0.69</td>
</tr>
<tr>
<td>RCA</td>
<td>1.17 (0.31–4.35) 0.82</td>
<td>0.25 (0.01–4.54) 0.35</td>
<td>1.96 (0.33–11.47) 0.46</td>
</tr>
<tr>
<td>Right posterior descending artery/right posterolateral branch</td>
<td>0.46 (0.13–1.67) 0.24</td>
<td>0.17 (0.01–3.78) 0.26</td>
<td>0.65 (0.09–4.79) 0.68</td>
</tr>
<tr>
<td>Circumflex artery</td>
<td>0.56 (0.15–2.05) 0.38</td>
<td>0.06 (0.01–1.12) 0.06</td>
<td>1.24 (0.22–6.93) 0.81</td>
</tr>
<tr>
<td>Obtuse marginal/left posterolateral branches/ramus intermedius</td>
<td>0.79 (0.20–3.22) 0.75</td>
<td>0.16 (0.01–2.91) 0.21</td>
<td>0.65 (0.09–4.79) 0.68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CTA segment characteristics</th>
<th>(a) Overall Misdiagnosis</th>
<th>(b) FN Diagnosis</th>
<th>(c) FP Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment tortuosity</td>
<td>3.54 (2.44–5.14) &lt;0.001</td>
<td>3.12 (1.89–5.17) &lt;0.001</td>
<td>5.22 (3.00–9.11) &lt;0.001</td>
</tr>
<tr>
<td>Vein crossing</td>
<td>2.13 (1.42–3.19) &lt;0.001</td>
<td>2.04 (1.14–3.62) 0.016</td>
<td>2.58 (1.28–5.17) 0.008</td>
</tr>
<tr>
<td>Motion artifact–related suboptimal segment image quality</td>
<td>1.39 (0.98–1.98) 0.068</td>
<td>1.45 (0.81–2.62) 0.21</td>
<td>1.30 (0.77–2.19) 0.34</td>
</tr>
<tr>
<td>Presence of segmental coronary calcification</td>
<td>2.49 (1.73–3.58) &lt;0.001</td>
<td>0.50 (0.29–0.86) 0.012</td>
<td>10.16 (5.23–19.77) &lt;0.001</td>
</tr>
<tr>
<td>Segment diameter (per 1-mm increment)</td>
<td>0.48 (0.36–0.63) &lt;0.001</td>
<td>0.40 (0.25–0.65) 0.008</td>
<td>0.49 (0.33–0.73) &lt;0.001</td>
</tr>
<tr>
<td>Mean segment luminal opacification (per 10-HU increment)</td>
<td>1.00 (0.98–1.01) 0.75</td>
<td>0.96 (0.94–0.99) 0.008</td>
<td>1.03 (1.00–1.05) 0.056</td>
</tr>
</tbody>
</table>

*Generalized estimating equations models accounted for within-patient clustering of segment characteristics. [Left main artery as referent. Cl = confidence interval. OR = odds ratio; other abbreviations as in Table 1.}
finding may be our adaptive adjustment of tube current to BMI and protocol-stipulated prescription of beta-blockers. A history of percutaneous coronary intervention surrogated higher disease prevalence among nonstented coronary segments in our studied population and independently conferred an increased risk for patient-level FN diagnosis, confirming the dependency of CTA accuracy on the pre-test probability of CAD (23).

We and others have shown that high calcium scores are associated with lower patient-level specificity and negative predictive level (5,19,20,23). Consistent with these reports, the current study found that a higher Agatston score independently increases the risk of patient-level FP diagnosis. Of note, we also found that the absence of coronary calcification is an independent predictor of stenosis under-recognition. We have previously reported among our trial cohort that the absence of coronary calcification does not exclude obstructive CAD (24) and that overall segment-level diagnostic inaccuracy is lower in noncalcified arterial segments of lower disease prevalence than in calcified coronary artery segments (25). In the present study, we establish the absence of coronary calcification as an underappreciated independent risk marker for FN diagnoses. Our results suggest that the absence of calcification may reduce a reader’s vigilance for stenoses and that potential lesions—without obvious (i.e., calcified) evidence of atherosclerosis—may be dismissed as artifacts.

Aside from intrinsic segment properties, intrarterial luminal enhancement and conspicuity of juxta-arterial cardiac veins emerge as independent factors affecting segment-level accuracy. Previous studies have shown higher unadjusted segment-level sensitivity and positive predictive value in patients achieving greater vascular contrast enhancement at the aortic root and origins of the left main and right coronary arteries (26). Our adjusted segment-specific luminal attenuation analyses affirm the importance of optimizing luminal contrast opacification to avert FN diagnoses (Fig. 3). Conspicuity of juxta-arterial venous structures is first identified associated with segment-level misinterpretations. Consequential to partial volume averaging, focal luminal attenuation at the over-crossed arterial

![Figure 1. False-Positive Diagnosis of Obstructive Coronary Artery Disease by Computed Tomography Angiography](image)
segment may appear artifactually lower or higher, potentially mimicking or masking stenosis, respectively (Fig. 4). These pitfalls advocate for optimized contrast bolus timing to achieve high intra-arterial while minimizing venous contrast enhancement.

**Study limitations.** The principal limitation of this investigation is the use of categoric decision points for determining the absence or presence of obstructive CAD, which, although almost invariably used for clinical investigations, may not reflect clinical practice. The use of specific thresholds to define disease is also associated with observer bias that may affect diagnostic accuracy (23). Our study was performed in a selected cohort with clinical indications for invasive coronary angiography. Our findings may not necessarily generalize to lower-risk populations, for whom CTA is more intended for CAD assessment. Although this is one of the largest multicenter investigations, the number of misdiagnosed patients is still modest; thus, implications of our patient-level associations should be considered as hypothesis generating, advocating for larger

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**Figure 2. Minor Cardiac Motion Affecting the Quantification of Coronary Artery Stenosis by CTA**

(A) Minor cardiac motion can lead to slightly smaller lumen appearance by computed tomography (arrow) compared with conventional angiography (arrow, B). Overestimation of lumen narrowing by CTA compared with quantitative conventional angiography resulted in FP diagnosis of obstructive coronary artery disease. Visualization of atherosclerotic plaque at the lesion site by computed tomography also may have contributed to the impression of significant lumen narrowing. Abbreviations as in Figure 1.

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**Figure 3. FN Diagnosis of Obstructive Coronary Artery Disease by CTA**

(A) Right coronary artery with poor contrast filling, which does not allow visualizing the site of a subtotal occlusion (arrow). (B) The corresponding invasive angiogram revealing the subtotal occlusion in the proximal right coronary artery (arrow). Abbreviations as in Figures 1 and 2.
confirmative studies. Given the effort entailed in our detailed segment-level analysis and the large number of TN segments within our entire multicenter cohort, we pre-specified and analyzed segment-level features of diagnostic inaccuracy on only a randomly selected TN-segment subset as comparative control. Our TN segment characteristics may thus be subjected to potential selection bias. However, we verified that the proportional constitution of segments of the different major vessels within this randomly selected TN-segment subset and the remainder of all nonselected TN segments in our entire patient cohort was not significantly different (Online Appendix 2).

CONCLUSIONS

In this systematic evaluation of factors associated with diagnostic inaccuracy for coronary artery stenosis assessment by CTA compared with QCA in a multicenter diagnostic study, we observed pitfalls as well as clinical and CTA features predictive of patient- and segment-level CTA misdiagnoses. Our observations particularly reveal the absence of coronary calcification as an independent risk marker for under-recognition of stenoses defined by QCA. Specific segment-level CTA features, notably small segment caliber, segment tortuosity, suboptimal intra-arterial contrast enhancement, and juxta-arterial venous conspicuity, are independent predictors for segment-level misdiagnoses. Knowledge and appropriate considerations of these CTA predictors of misdiagnosis may improve limitations awareness, and accuracy in clinical CTA interpretation.

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Key Words: accuracy of computed tomography angiography false-negative false-positive.

APPENDIX

For additional tables, please see the online version of this article.