Diagnostic accuracy of second generation dual source computed tomography coronary angiography with iterative reconstructions: a real world experience

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Purpose

1. Computed tomography coronary angiography (CTCA) has become a part of clinical practice for diagnosing obstructive coronary artery disease (CAD) [1-8]. Studies demonstrating the accuracy of 64-slice CTCA used, for the most part, validation methodologies [i.e. with conventional coronary angiography (CCA)] as a reference standard and in a high-risk population) [3-7, 9-18]. Few studies report its real efficacy in the clinical settings [19]. In those studies, diagnostic performance was lower than previously reported in the main studies of diagnostic accuracy [19].

2. Guidelines and international panels recommend using CTCA in patient populations at low to intermediate risk, where stress tests are inconclusive or cannot be performed [8, 20-22]. The introduction of new technologies with improved temporal, spatial and contrast resolution, such as the second-generation dual-source computed tomography (DSCT), offers the possibility of making the technique more reliable and robust. In addition, the introduction of iterative reconstruction algorithms provides improvement in image quality by significantly reducing image noise [19].

3. The aim of this study was to compare the diagnostic performance of CTCA using a second-generation DSCT system and iterative reconstructions with CCA in detecting obstructive CAD.
Methods and Materials

Study population

From June 2010 to February 2011, 160 patients (85 men; mean age, 61.2±11.6 years) with suspected CAD [chest pain and/or abnormal electrocardiogram (ECG) suggestive of myocardial ischaemia] and positive CCA were enrolled in the study. All patients underwent CTCA and CCA. Only patients with sinus rhythm who had never undergone percutaneous angioplasty or coronary artery bypass graft surgery and were able to maintain a breathhold for at least 5 s were included. Patients with acute coronary syndrome, with absolute contraindications to intravenous administration of iodiate contrast material (e.g., known allergy, kidney failure or thyroid disorders) were excluded. The ethics committee approved the study, and all patients provided informed consent.

Patient preparation

Patients with a heart rate (HR) >60 bpm and without specific contraindications received a 5-mg intravenous dose of betablockers (atenolol, Tenormin, AstraZeneca). In the absence of contraindications, sublingual nitrate (dinitrate isosorbide, Carvasin 5 mg, Wyeth Lederle) was administered prior to the scan.

CTCA scan protocol and image reconstruction

The study was performed with a DSCT system with 128 (64×2×2) slices (Definition Flash, Siemens, Forchheim, Germany) [4, 5]. Two scans were performed in all patients: one to visualise coronary artery calcium (a) and one angiography scan (b). The following parameters were used for the scans [5, 19]:

a) Sequential scan protocol: Number of slices per rotation 62×2×2; gantry rotation time 280 ms; temporal resolution 75 ms; scan direction craniocaudal; reconstruction algorithm 180°; acquisition time window 70% of the RR interval; tube voltage 120 kV; tube current 150 mAs. Images were reconstructed with the following parameters: effective slice thickness 3 mm; reconstruction increment 1.5 mm; field of view (FOV) 150-160 mm; convolution kernel for calcium score (B35f).

b) Spiral scan protocol: Number of slices per rotation 62×2×2; slice thickness 0.6 mm; gantry rotation time 280 ms; temporal resolution 75 ms; scan direction craniocaudal; reconstruction algorithm 180°; patient table feed/pitch variable and adapted to HR (range 0.16-0.35); tube voltage 100-120 kV [according to patient body mass index (BMI)]; tube
current 320-370 mAs (according to patient BMI); effective slice thickness 0.6-0.75 mm; reconstruction increment 0.4 mm; FOV 150-160 mm; convolution kernel medium smooth with first-generation iterative reconstruction (126-146f; IRIS, Siemens, images/second vs. 20 images/second). Prospective tube current modulation was used with a high-dose window from 65% to 80% of the RR interval and a MinDose protocol (Siemens, Germany) in the remaining phases of the cardiac cycle (i.e. 4% of maximum amperes; Fig. 1). Mean dose-length product was 517±153, which corresponds to an effective dose (conversion factor 0.014 mSv·mGy−1·cm−1 for the chest) of 7.2±2.1 mSv [7]. Between 70 ml and 100 ml of iodinated contrast material (Iomeprol, Iomeron 400, Bracco, Milan, Italy) was administered at an injection rate of 5-6 ml/s using an automatic injector (Stellant, MedRAD, Pittsburgh, PA, USA) attached to an 18- to 20-gauge needle cannula positioned in an antecubital vein [5]. Coronary artery enhancement was optimised by using the bolus-tracking technique (CARE bolus, Siemens, Forchheim, Germany) to synchronise contrast material arrival in coronary arteries with the beginning of the scan [5, 23]. Angiography scan data were obtained during a single breath-hold of 4-7 s (according to HR and adaptive pitch). Retrospective reconstructions based on the ECG signal were done on the angiography scans to obtain images free from motion artefacts in the maximum-dose time window (65-80% of the RR interval). The optimal diastolic phase was automatically obtained within this time window (Best-Phase, Siemens, Germany). Additional reconstructions in different reconstruction time windows of the cardiac cycle were analysed whenever this was considered necessary (e.g. in cases of persistent residual heart motion, which reduces the diagnostic quality of the images).

**CTCA image evaluation**

All CTCA images were evaluated in consensus by two readers with 10 and 5 years of experience, respectively, in the field and who were unaware of CCA findings. All conventional visualisation techniques were used by the operator (axial images, multiplanar images, curved multiplanar images, maximum intensity projection, volume rendering) on a dedicated workstation with a cardiology software platform (SyngoVia, Siemens, Germany). The operator identified the coronary artery segments using the modified American Heart Association 17-segment classification [24]. Segments were classified as being without significant stenosis (normal or with wall irregularities or stenosis <50%) or with significant stenosis (stenosis >50%) using the commonly applied classifications [3, 6, 7].

**Conventional coronary angiography**

CCA was performed within 2 weeks of the CTCA examination using a conventional technique. The operator was aware of data from the CTCA report and images and identified coronary artery segments using the modified American Heart Association
(AHA) 17-segment classification [24]. All segments regardless of diameter were included in the comparison with CTCA. Segments were classified as being without significant stenosis (normal or with wall irregularities or noncritical stenosis <70%) or with significant stenosis (critical stenosis .70%; in the left main coronary artery .50%) using the conventional classifications and guidelines. Coronary stenoses were evaluated by the operator during the angiography session in the maximum stenosis view and using visual evaluation. Mean effective radiation dose for CCA (diagnostic procedure alone) was 5.6 #} 3.8mSv.

Statistical analysis

The diagnostic performance of CTCA was evaluated by comparing reports archived in the hospital radiology information system for CTCA and CCA, respectively. Reports were drawn up immediately after the procedures. Mean reporting time was 10 min for CTCA and 8 min for CCA. Lesions were considered significant if stenosis was .50% for CTCA and .70% for CCA. Accuracy was then calculated as sensitivity, specificity and positive and negative predictive values (PPV and NPV), with 95% confidence intervals (CI) calculated with binomial expansion. Disease prevalence and positive and negative likelihood ratios (LR+ and LR-, respectively) with 95% CI were also calculated. Comparison between CTCA and CCA was performed per segment, per vessel and per patient on the entire patient population. Statistical analysis was carried out with a dedicated software package (Statistical Package for the Social Sciences, version 11.5, SPSS Inc., Chicago, IL, USA).
Table 1: Description of the study population. SD, standard deviation; M/F, males/females; BMI, body mass index; bpm, beats per minute; LVEF, left ventricle ejection fraction.

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Fig. 1: Scan protocol and dose modulation. The maximum dose is delivered from 65% to 80% of the RR interval. In the remaining phases, the tube current drops to 4% of the dose. Within this modulation phase, reconstruction window position can be chosen (width 75ms). ECG, electrocardiogram.

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Results

No patient or segment was excluded from the analysis. β-blockers were administered i.v. in 95% of patients (152/160). Mean HR was 64.3±11.9 bpm. Patient population details are reported in Table 1 [1]. CAD and CAA disease prevalence was 30% (Table 2). A total of 70% (112/160) of patients had no critical stenoses at CCA. Approximately one tenth of patients had single-vessel disease (9.4%, 15/160), and one in 25 had three-vessel disease (3.8%, 6/160). Agatston calcium score was intermediate, with ample variability [mean ± standard deviation (SD) 178.6±346.1; median 17; range 0-2,123], thus revealing a heterogeneous population with a medium- to low prevalence of CAD. CTCA accuracy for identifying significant lesions with a per-segment, per-vessel and per-patient evaluation is reported in Table 3 and Figs. 2-4. Accuracy values are comparable with those of validation series reported in the literature [7, 14-16, 18, 25-27].

Per-segment evaluation

A total of 2,471 segments were included in the comparison with CCA. Of these, 192 (7.8%) showed critical stenosis (Figs. 1 and 2). There were 152 false positives and 19 false negatives at CTCA. This produced a sensitivity of 90% and specificity of 93%.

Per-vessel evaluation

A total of 637 coronary artery vessels were included in the evaluation. Of these, 80 (12.4%) showed critical stenosis at CCA. There were 49 false positive and two false negative results at CTCA. This produced a sensitivity of 98% and specificity of 91%. The best accuracy values were recorded in the left main coronary artery and the left anterior descending coronary artery (sensitivity 100%).

Per-patient evaluation

A total of 160 patients were included in the comparison with CCA. Of these, 48 (30.0%) showed at least one critical stenosis at CCA (Figs. 5 and 6). There were 19 false positive and 0 false negative results at CTCA. Accuracy values were excellent, with a sensitivity and NPV of 100%.
<table>
<thead>
<tr>
<th>Population</th>
<th>Total</th>
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<tbody>
<tr>
<td>Number of patients</td>
<td>160</td>
</tr>
<tr>
<td>Age (years; mean±SD)</td>
<td>61.2±11.6</td>
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<td>Gender (M/F)</td>
<td>85/75</td>
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</table>

<table>
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<tr>
<th>Symptoms</th>
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<tbody>
<tr>
<td>Stable angina, n (%)</td>
<td>25 (16)</td>
</tr>
<tr>
<td>Atypical chest pain, n (%)</td>
<td>81 (50)</td>
</tr>
<tr>
<td>Silent ischaemia, n (%)</td>
<td>54 (34)</td>
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</tbody>
</table>

<table>
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<tr>
<th>Cardiovascular risk factors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension, n (%)</td>
<td>72 (45)</td>
</tr>
<tr>
<td>Hypercholesterolaemia, n (%)</td>
<td>46 (29)</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>22 (14)</td>
</tr>
<tr>
<td>Cigarette smoking, n (%)</td>
<td>23 (14)</td>
</tr>
<tr>
<td>Family history, n (%)</td>
<td>53 (33)</td>
</tr>
<tr>
<td>Obesity (BMI≥30 kg/m²; %)</td>
<td>5 (3)</td>
</tr>
<tr>
<td>Calcium score (Agatston; mean±SD)</td>
<td>178.6±346.1</td>
</tr>
<tr>
<td>Heart rate (bpm; mean±SD)</td>
<td>64.3±11.9</td>
</tr>
<tr>
<td>LVEF (%) (mean±SD)</td>
<td>54.2±9.6</td>
</tr>
</tbody>
</table>

**Table 2:** Description of the study population. SD, standard deviation; M/F, males/females; BMI, body mass index; bpm, beats per minute; LVEF, left ventricle ejection fraction

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Table 3: Prevalence of coronary artery disease measured with conventional coronary angiography.

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Table 4: Diagnostic accuracy. Criterion used to compare techniques: lumen reduction \#50\% in CTCA and \#70\% in conventional coronary angiography (CCA) (except for the left main coronary artery, for which the criterion was \#50\%) assessed with direct vision. Accuracy values are presented in percentages, with the 95\% confidence intervals calculated with binomial expansion in parentheses. No., number; TP, true positive; TN, true negative; FP, false positive; FN, false negative; PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR-, negative likelihood ratio; RCA, right coronary artery; LM, left main coronary artery; LAD, left anterior descending artery; CX, circumflex coronary artery; HR, heart rate; NA, nonassessable

Fig. 2: Diagnostic accuracy parameters expressed in percentages. Sens., sensitivity; Spec., specificity; PPV, positive predictive value; NPV, negative predictive value; Segm., per-segment evaluation; Vessel, per-vessel evaluation; Pat., per-patient evaluation.

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**Fig. 3:** Positive (LR+) and negative (LR-) likelihood ratios. Thin bars depict the 95% confidence intervals of the LR values. Segm., per-segment evaluation; Vessel, per-vessel evaluation; Paz., per-patient evaluation.

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Fig. 4: Conditional probabilities in the study population. Segments, per-segment evaluation; Vessels, per-vessel evaluation; Patients, per patient evaluation.

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**Fig. 5:** a-h Negative CTCA. This 56-year-old, hypertense and dyslipidaemic man (body mass index 28) presented with atypical chest pain and abnormal electrocardiogram suggestive of ischaemia. CTCA (a-e) shows coronary arteries with no significant stenoses both in the volume-rendered images (a,b) and the curved multiplanar images (c: right coronary artery; d: left anterior descending coronary artery; e: circumflex coronary artery). CCA (f-h) confirms the absence of significant stenoses. The examination was performed with a heart rate of 58 bpm and a radiation dose of 8.9 mSv.

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Fig. 6: a-e Positive CTCA. This 54-year-old, hypertense man (body mass index 26) with a family history of cardiovascular disease presented with atypical chest pain and abnormal electrocardiogram suggestive of ischaemia. CTCA (a-c) shows a left anterior descending coronary artery without significant stenosis (b) and a circumflex coronary artery with stenosis >50% in the context of a very irregular section of the wall (arrowhead, c). CCA (d,e) confirms stenosis of the circumflex artery (arrowhead, e). The examination was performed with a heart rate of 55 bpm and a radiation dose of 5.9 mSv.

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Conclusion

The accuracy of CTCA with a second-generation DSCT system and using iterative reconstructions enables the technique to be used as a noninvasive anatomical reference test for the diagnosis and exclusion of obstructive CAD.
References


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