Read with expert: CCT in challenging patients

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Who are the challenging patients for CCT?

- The open issue of spatial resolution for high risk patients for CAD
- The open issue of temporal resolution for patients with heart rhythm disorder
- The open issue of effective radiation dose for mid age patients
- The open issue of functional evaluation of CAD: FFRct and stress CTP
THE NEW TECHNOLOGY

• New imaging chain redesigned to deliver uncompromised image quality & clinical capabilities
  – 160 mm detector coverage
  – 0.28 s rotation speed combined with intelligent motion correction
  – Best-in-class 0.23 mm spatial resolution and 18.2 lp/cm cardiac resolution thanks to Gemstone Detector
  – Next generation iterative reconstruction - ASiR-V reduces dose up to 82%
  – Future proof platform tested to support 0.2 s/rotation and ultra-fast kV switching
THE OPEN ISSUE OF SPATIAL RESOLUTION

GE Gemstone Scintillator

Garnet crystalline structure + Rare Earth phosphor composition

Best-in-class 0.23 mm spatial resolution and 18.2 lp/cm cardiac resolution thanks to Gemstone Detector.
THE OPEN ISSUE OF SPATIAL RESOLUTION

G. Pontone, E. Bertella, S. Mushtaq, M. Loguercio, S. Cortinovis, A. Baggiano, E. Conte, A. Annoni, A. Formenti, M. Petullà, D. Andreini

<table>
<thead>
<tr>
<th></th>
<th>SDCT</th>
<th>HDCT</th>
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<tbody>
<tr>
<td>Segment-based analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(all segments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>258/266 (97 [95, 99])</td>
<td>206/208 (99 [98, 100])</td>
<td>.15</td>
</tr>
<tr>
<td>Specificity</td>
<td>1079/1190 (91 [89, 92])</td>
<td>1227/1275 (96 [95, 97])</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>1079/1087 (99 [99, 99])</td>
<td>1227/1229 (100 [100, 100])</td>
<td>.05</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>258/369 (70 [65, 75])</td>
<td>206/254 (81 [76, 86])</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Accuracy</td>
<td>1337/1457 [92 [90, 93])</td>
<td>1433/1483 [97 [96, 98]]</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>
THE OPEN ISSUE OF TEMPORAL RESOLUTION

- Intra-cycle motion correction algorithm
- 0.28s rotation speed (0.20 sec for the next update)
- 160 mm whole organ coverage (16 cm z-axis coverage with 256 detector rows)

**IntraCycle Motion Correction Algorithm**

Intelligent Motion Correction to address the challenge of coronary artery motion blurring:

- Characterize vessel motion by utilizing adjacent cardiac phases
- Determine actual position of the vessel at target phase
- Adaptively compensate for residual coronary motion at that phase, utilizing information from adjacent cardiac phases within a single cardiac cycle
THE OPEN ISSUE OF TEMPORAL RESOLUTION

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Impact of an intra-cycle motion correction algorithm on overall evaluability and diagnostic accuracy of computed tomography coronary angiography

Gianluca Pontone¹ · Daniele Andreini¹,² · Erika Bertella¹ · Andrea Baggiano¹ · Saïma Mushtaq¹ · Monica Loguercio¹ · Chiara Segurini¹ · Edoardo Conte¹ · Virginia Beltrame¹ · Andrea Annoni¹ · Alberto Formenti¹ · Maria Petullà¹ · Andrea I. Guaricci³ · Piero Montorsi¹,² · Daniela Trabattoni¹ · Antonio L. Bartorelli¹,² · Mauro Pepi¹

Pontone G et al, Eur Radiol 2015
THE OPEN ISSUE OF TEMPORAL RESOLUTION

- **Intra-cycle motion correction algorithm**
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<tr>
<th>Segment-based analysis</th>
<th>SRA</th>
<th>MCA</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity, n (% CI 95%)</td>
<td>74/104 (71 [62-80])</td>
<td>72/104 (69 [60-78])</td>
<td>0.76</td>
</tr>
<tr>
<td>Specificity, n (% CI 95%)</td>
<td>401/547 (73 [70-77])</td>
<td>474/547 (87 [84-90])</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Negative predictive value, n (% CI 95%)</td>
<td>401/431 (93 [91-95])</td>
<td>474/506 (94 [92-96])</td>
<td>0.69</td>
</tr>
<tr>
<td>Positive predictive value, n (% CI 95%)</td>
<td>74/220 (34 [27-40])</td>
<td>72/145 (50 [42-58])</td>
<td>0.002</td>
</tr>
<tr>
<td>Accuracy, n (% CI 95%)</td>
<td>475/651 (73 [70-76])</td>
<td>546/651 (84 [81-87])</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vessel-based analysis</th>
<th>SRA</th>
<th>MCA</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity, n (% CI 95%)</td>
<td>56/61 (92 [85-99])</td>
<td>55/61 (90 [83-98])</td>
<td>0.75</td>
</tr>
<tr>
<td>Specificity, n (% CI 95%)</td>
<td>21/74 (28 [18-39])</td>
<td>46/74 (62 [51-73])</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Negative predictive value, n (% CI 95%)</td>
<td>21/26 (81 [66-96])</td>
<td>46/52 (88 [80-97])</td>
<td>0.36</td>
</tr>
<tr>
<td>Positive predictive value, n (% CI 95%)</td>
<td>56/109 (51 [42-61])</td>
<td>55/83 (66 [56-76])</td>
<td>0.038</td>
</tr>
<tr>
<td>Accuracy, n (% CI 95%)</td>
<td>77/135 (57 [49-65])</td>
<td>101/135 (75 [67-82])</td>
<td>0.002</td>
</tr>
</tbody>
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<th>Patient-based analysis</th>
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<th>MCA</th>
<th>P value</th>
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</thead>
<tbody>
<tr>
<td>Sensitivity, n (% CI 95%)</td>
<td>34/34 (100 [100-100])</td>
<td>34/34 (100 [100-100])</td>
<td>NA</td>
</tr>
<tr>
<td>Specificity, n (% CI 95%)</td>
<td>0/11 (0 [0-0])</td>
<td>8/11 (73 [46-99])</td>
<td>0.0004</td>
</tr>
<tr>
<td>Negative predictive value, n (% CI 95%)</td>
<td>0/0 (NA)</td>
<td>8/8 (100 [100-100])</td>
<td>NA</td>
</tr>
<tr>
<td>Positive predictive value, n (% CI 95%)</td>
<td>34/45 (76 [63-88])</td>
<td>34/37 (92 [83-100])</td>
<td>0.05</td>
</tr>
<tr>
<td>Accuracy, n (% CI 95%)</td>
<td>34/45 (76 [63-88])</td>
<td>42/45 (93 [86-100])</td>
<td>0.019</td>
</tr>
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</table>

CI confidence interval, NA not applicable

Pontone G et al, Eur Radiol 2015
THE OPEN ISSUE OF TEMPORAL RESOLUTION

Pontone G et al, Eur Radiol 2015
THE OPEN ISSUE OF TEMPORAL RESOLUTION

- Intra-cycle motion correction algorithm
- 0.28s rotation speed (0.20 sec for the next update)
- 160 mm whole organ coverage (16 cm z-axis coverage with 256 detector rows)

Diagnostic accuracy of Coronary CT Angiography Performed With a Novel Whole-Heart Coverage High-Definition CT Scanner in Atrial Fibrillation Patients

Running title: Diagnostic accuracy of a new scanner in AF patients

Authors: \(^1\)Daniele Andreini, MD, PhD, FESC, FSCCT, \(^1\)Gianluca Pontone, MD, PhD, FESC, \(^1\)Saima Mushtaq, MD, \(^1\)Edoardo Conte, MD, \(^3\)Marco Perchinunno, MD, \(^1\)Marco Guglielmo, MD, \(^1\)Valentina Volpato, MD, \(^1\)Andrea Annoni, MD, \(^1\)Andrea Baggiano, MD, \(^1\)Alberto Formenti, MD, \(^1\)Maria Elisabetta Mancini, MD, \(^1\)Virginia Beltrami, MD, \(^1,2\)Cesare Fiorentini, MD, \(^1,4\)Antonio L. Bartorelli, MD, and \(^1\)Mauro Pepi, MD, FESC.
THE OPEN ISSUE OF TEMPORAL RESOLUTION

Table 3. Comparison of the diagnostic accuracy of CCTA for the detection of significant (>50%) stenosis between group 1 and group 2 (segment-based analysis)

<table>
<thead>
<tr>
<th>Segment-based analysis (using evaluable segments only)</th>
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<tbody>
<tr>
<td>N</td>
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<tr>
<td>---</td>
</tr>
<tr>
<td>Group 1</td>
</tr>
<tr>
<td>Group 2</td>
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</tbody>
</table>

Table 4. Comparison of the diagnostic accuracy of CCTA for the detection of significant (>50%) stenosis between group 1 and group 2 (patient-based analysis)

<table>
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<tbody>
<tr>
<td>N</td>
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<tr>
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<tr>
<td>Group 1</td>
</tr>
<tr>
<td>Group 2</td>
</tr>
</tbody>
</table>

FN: false negative; FP: false positive; NPV: negative predictive value; PPV: positive predictive value; Se: sensitivity; Sp: specificity; TN: true negative; TP: true positive.

Group 1: AF pts; Group 2: SR pts

Andreini D, Pontone G et al, Submitted
CCTA evaluation in a patient with rapid atrial fibrillation. Despite atrial fibrillation and acquisition at a HR of 94 bpm (panel A), CCTA was able to evaluate all coronary tree with good image quality and without motion blurring, allowing to rule-out significant coronary stenosis in LMCA-LAD (panel B), LCX (panel C) and RCA (panel D).

LAD=left anterior descending artery; LCX=left circumflex artery; LMCA=left main coronary artery; RCA=right coronary artery.
Detection of two-vessel coronary artery disease by CCTA confirmed with ICA in a patient with atrial fibrillation. Despite atrial fibrillation during the scan (panel A), CCTA was able to detect significant stenosis of mid LAD (panel B, arrow) and LCX (panel D, arrow). Both lesions were confirmed by ICA (panel C and panel E, arrows).

*LAD* = left anterior descending artery; *LCX* = left circumflex artery; *LMCA* = left main coronary artery; *RCA* = right coronary artery.

**Group 1: AF pts; Group 2: SR pts**

Andreini D, Pontone G et al, Submitted
THE OPEN ISSUES OF RADIATION DOSE

Hi Res Lowdose CCTA @ 80 kV

Acquisition
Axial
80 kV
400 mA
0.28 sec/rot
50 ml CM+50 ml Saline fl. 5.0
HD Std kernel + ASiR V 50%
2.3 mSv CTDvol
37.8 mSv-cm DLP

0.5 mSv^4
20 BMI
Phase 75%
49 BPM
THE OPEN ISSUE OF FUNCTIONAL EVALUATION OF CAD
**THE OPEN ISSUE OF FUNCTIONAL EVALUATION OF CAD**

**Visual assessment:** Areas of reduced perfusion appear hypoenhanced compared with the normal myocardium, which implies either myocardial ischemia or myocardial infarction.

**Strengths:** Fast analysis

**Pitfalls:** Normal left ventricular myocardial enhancement demonstrates substantially lower attenuation in the lateral wall when compared with the anterior, septal, and inferior walls in patients with normal coronary arteries. The lateral myocardial wall is located adjacent to the air within the lungs and is not subjected to the same beam-hardening effect.

Choi AD et al, JCCT 2014
THE OPEN ISSUE OF FUNCTIONAL EVALUATION OF CAD

*Quantitative assessment*: Myocardial Blood Flow (MBF): maximum TAC slope/maximum AIF (ml/100 ml/min)

Images in a 75-year-old woman with typical symptoms of chest pain. (a) Curved multiplanar reformat of the left anterior descending coronary artery shows a subtotal occlusion of the middle left anterior descending coronary artery (arrow). (b) Stress myocardial CT perfusion color-coded map in a four-chamber view, from dynamic CT acquisition with a DS CT scanner, shows a hypoperfused area at the level of the septum and the apex (*). Both myocardial areas look thinner compared with the other myocardial segments. (c) MR image acquired with delayed enhancement in a four-chamber view.
The PERFECTION Prospective Study

comparison between stress cardiac computed tomography PERfusion versus Fractional flow rEserve CT derived In the evaluation of suspected cOroNary artery disease.

Patients with pretest likelihood of CAD ≥ 50% scheduled for clinically indicated invasive coronary angiography and no contraindications to CTCA or FFR\(_{CT}\)

**TIMELINE**

**COHORT 1**  
STATIC STRESS CTP  
(N: 150 patients)

**COHORT 2**  
DYNAMIC STRESS CTP  
(N: 150 patients)

FFR\(_{CT}\) – Visual CTP evaluation – Quantitative CTP (TPR & MBF)

ICA + Invasive FFR

Pontone G et al JCCT 2016
CLINICAL CASE 1 (Perfection # 22)

A 83-year-old woman, known for recent onset of typical chest pain, performed SPECT, resulted positive for reversible perfusion deficit at mid-basal portion of postero-lateral wall.

- BP 140/80 mmHg; W 83 Kg; H 167 cm; BMI 30 kg/m².
- Scan parameters:
  ○ Tube voltage: 120 KVp
  ○ Tube current: 500 mA
  ○ Acquisition window: 40-80% cardiac cycle
  ○ Reconstruction phase: 40-80% cardiac cycle
  ○ Total DLP: 610.48 mGy/cm (8.5 mS)
CLINICAL CASE 1 - Summary

Practice guidelines

CAD-RADS™ Coronary Artery Disease – Reporting and Data System. An expert consensus document of the Society of Cardiovascular Computed Tomography (SCCT), the American College of Radiology (ACR) and the North American Society for Cardiovascular Imaging (NASCI). Endorsed by the American College of Cardiology

Ricardo C. Cury a, *, Suhny Abbara b, Stephan Achenbach c, Arthur Agatston d, Daniel Berman e, Matthew Budoff f, Karin Dill g, Jill Jacobs h, Christopher Maroules i, Geoffrey Rubin j, Frank J. Rybicki k, Joseph Schoepf l, Leslee Shaw m, Arthur Stillman n, Charles White o, Pamela Woodard p, Jonathon Leipsic q
**CLINICAL CASE 1 - Summary**

- **cCTA** → CAD-RADS 5 (M1 occlusion) → Consider ICA and/or viability assessment

- **FFRct** → 2 vessels disease < 0.80 → Consider ICA

- **CTP** → Reversible perfusion defect in septal-anterior and postero-lateral wall → Consider ICA

- **ICA** → Intermediate mid-distal LAD stenosis (eterocoronary vessels to LCx/M)
  - critical LCx/M stenoses → Consider OMT or PCI on LCx/M

**KEY MESSAGE 1:** Functional tool (FFRct and CTP) to provide additional value to limited image quality in challenging patient due to severe calcifications
A 57-year-old man was resuscitated 30 years ago from SCD (VF) occurred after onset of chest pain. At EKG, subepicardial lateral ischemia. At ICA, bivessel disease, not treated. Afterwards, Echo-stress and EPS both negative.

Recent performing of Ex-EKG, not diagnostic, and SPECT, positive for inducible ischemia at mid-basal portion of infero-lateral wall.

- BP 150/75 mmHg; W 67 Kg; H 165 cm; BMI 25 kg/m².
- Scan parameters:
  - Tube voltage: 100 KVP
  - Tube current: 600 mA
  - Acquisition window and reconstruction phase: 75% cardiac cycle
  - Total DLP: 323.01 mGy/cm (4.5 mS)
CLINICAL CASE 2 - Summary

- cCTA → CAD-RADS 5 (3Vs occlusion) → Consider ICA and/or viability assessment
- FFRct → Two values < 0.80 (LAD & RCA) * → Consider ICA
- CTP → Large reversible perfusion defect (Anteroseptal, inferior, lateral) → Consider ICA
- ICA → Significant three-vessel disease → Consider CAGB/PCI

KEY MESSAGE 2: FFRct and CTP as useful tool to plan the revascularization strategy in multiple vessel disease
CLINICAL CASE 3 (Perfection # 44)

A 61-year-old man with multiple CV risk factors recently performed Ex-EKG, valued as positive for inducible ischemia for EKG criteria, being asymptomatic for chest pain.

- BP 140/70; W 70 Kg; H 177 cm; BMI 22 Kg/m².
- Scan parameters:
  ◦ Tube voltage: 100 KVP
  ◦ Tube current: 500 mA
  ◦ Acquisition window: 40-80% cardiac cycle
  ◦ Reconstruction phase: 75% cardiac cycle
  ◦ Total DLP: 300.9 mGy/cm (4.2 mS)
CLINICAL CASE 3 - Summary

- **cCTA** → CAD-RADS 3 (LAD intermediate stenosis) → Consider Functional assessment

- **FFRct** → LAD value < 0.80 (0.66) → Consider ICA

- **CTP** → Reversible perfusion defect on LAD territory + LCX territory → Consider ICA

- **ICA** → One-vessel disease (LAD) → Consider PCI on LAD

**KEY MESSAGE 3:** FFRct and CTP as useful tools to detect functional relevance of CAD. FFRct has the advantage to provide a per-lesion evaluation rather than a per-territory evaluation.
A 65-year-old man, known for paroxysmal AF and multiple CV risk factors, performed several stress test (mainly Ex-EKG and SPECT) in the last fifteen years because of atypical chest pain, always negative for inducible ischemia. Recently, he suffered outbreak of atypical chest pain, and the last Ex-EKG performed was valued as positive for inducible ischemia for EKG criteria.

- BP 135/80 mmHg; W 72 Kg; H 160 cm; BMI 28 kg/m².
- Scan parameters:
  ◦ Tube voltage: 100 KVP
  ◦ Tube current: 600 mA
  ◦ Acquisition window: 40-80% cardiac cycle
  ◦ Reconstruction phase: 70% cardiac cycle
  ◦ Total DLP: 331.41 mGy/cm (4.6 mS)
CLINICAL CASE 4 - Summary

- cCTA → CAD-RADS 3 (LAD & LCX moderate stenosis) → Consider functional assessment

- FFRct → All values > 0.80 → OMT

- CTP → Mild reversible perfusion defect on lateral wall → Consider ICA

- ICA → Moderate disease on LCx → OMT, FFR indicated

- FFR → All values > 0.80 → OMT

KEY MESSAGE 4: FFRct is not influenced by beam hardening artefacts as compared to stress CTP
CLINICAL CASE 5 (Perfection # 34)

A 51-year-old man with multiple CV risk factors, and known carotid artery disease, recently performed EKG characterized by T-wave abnormalities in inferior leads. Subsequently, he performed Ex-EKG, valued as positive for inducible ischemia.

- BP 135/75 mmHg; W 80 Kg; H 170 cm; BMI 28 kg/m².
- Scan parameters:
  - Tube voltage: 100 KVp
  - Tube current: 550 mA
  - Acquisition window: 40-80% cardiac cycle
  - Reconstruction phase: 75% cardiac cycle
  - Total DLP: 430.4 mGy/cm (6 mS)
Lumen
Ex: 96742367
Stripe Length: 18.4 cm
So: 403
Angle: 126.0° Right
LP: 91.2

RCA+PDA

0.6mm / 0.62sp
04:36:59 PM
W = 1005 L = 225
FFR 0.82
FFR 0.62
CLINICAL CASE 5 - Summary

- cCTA → CAD-RADS 4B (3 Vsls severe stenosis) → Consider ICA or functional assessment

- FFRct → Three values < 0.80 → Consider ICA

- CTP → Reversible perfusion defect in inferior wall and lateral wall → Consider ICA

- ICA → Two-vessel disease (RCA & M2) → Consider PCI on RCA and M2

KEY MESSAGE 5: The atherosclerotic plaque characteristics (APC) improve the prediction of significant invasive FFR by FFRct
Who is the winner?

“Diagnostic PERFORMANCE of stress echocardiography (Echo), stress single-photon-emission computed tomography (SPECT), positron emission tomography (PET), stress cardiac magnetic resonance (CMR), computed tomography coronary angiography (CTCA), stress perfusion computed tomography (CTP) and computed tomography fractional flow reserve (FFRCT) for the assessment of Coronary Artery Disease (CAD) versus invasive FFR (FFRi): a meta-analysis”

Pontone G ESC 2016 (PERFORMANCE-CAD study)
NEW PERSPECTIVES: who is the winner?

Summary of receiver operating characteristic curves for prediction of ischemia for a vessel (left panel) or patient model (right panel) as compared to invasive FFR. The \( Q^* \) statistic represents the point where sensitivity and specificity are equal.

AUC: area under the summary receiver operating characteristic curve; CMR cardiac magnetic resonance; CTCA computed tomography coronary angiography; CTP: stress myocardial computed tomography perfusion; Echo: stress echocardiography; FFR\textsubscript{CT}: Fractional Flow Reserve CT derived; PET positron emission tomography; SE: standard error; SPECT single-photon emission computed tomography.
A proposal of diagnostic algorithm to select patients with suspected CAD who could really receive benefits by ICA and consequential revascularization.

**CAD**: coronary artery disease; **CMR**: cardiac magnetic resonance; **CTCA**: computed tomography coronary angiography; **FFR\(_{CT}\)**: fractional flow reserve CTCA derived; **ICA**: invasive coronary angiography; **NEW PERSPECTIVES**: who is the winner?
Anatomy and physiology in ischaemic heart disease: a second honeymoon?

Gianluca Pontone*

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THANKS

Director of Cardiology
Prof. Cesare Fiorentini, MD

Area of Cardiovascular Imaging
Dr. Mauro Papi, MD

Cardiovascular MR Unit
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Radiology Unit
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