CORONARY ARTERY BYPASS GRAFT IMAGING WITH CT ANGIOGRAPHY AND ITERATIVE RECONSTRUCTION: QUANTITATIVE EVALUATION OF RADIATION DOSE REDUCTION AND IMAGE QUALITY

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CHUM:
Equipment loan by Philips Healthcare and Bayer Canada (CCL).
• **Invasive Catheter Angiography vs Computed Tomography (CT)**
  - Although catheter angiography has long been the diagnostic tool of choice, computed tomography angiography is increasingly employed.
  - In 2009, 227 CT scans were performed / 1000 habitants, for 69 million scans per year.\(^1\)
  - CT is less invasive, less costly and more rapid.

• **Efficiency:**
  a. **Detection of significant stenosis in coronary artery bypass grafts (CABG):**
     Sensibility: 94%  Specificity: 98%
  b. **Detection of occlusion in CABG:**
     Sensibility: 99%, Specificity: 99%\(^2\)

• However, CT scans have been associated with some of the largest radiation doses per examination, reaching almost 15 mSv/scan.\(^3\)

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• Different reconstruction algorithms can be employed to reconstruct CT scan images.

**Filtered back Projection (FBP)**
- Standard method
- Robust and rapid reconstruction
- Vulnerable to decreased photon count (i.e. dense neighbouring structures)
- Presence of noise, artefacts, etc.

**Iterative Reconstruction (IR)**
- Complex algorithms demanding powerful computerized bases
- Less sensitive to decreased photon count
- Employed to reduce radiation dose in computed tomography
AIM

• To assess radiation dose reduction achieved by reducing tube current along with the use of an hybrid IR algorithm (iDose⁴, Philips Healthcare, Cleveland, OH, USA).

• To compare image quality between IR and FBP reconstruction.
50 patients with CABG (IMA *, saphenous veins)

Standard Dose Protocol (n=25)
- Standard Tube Current
- FBP Reconstruction
- 41 evaluated grafts
  - 24 IMA
  - 17 Saphenous veins

Low Dose Protocol (n=25)
- 30% Lower Tube Current
- Iterative Reconstruction (iDose4 level 3)
  - Noise reduction Factor: 0.78
- 41 evaluated grafts
  - 24 IMA
  - 17 Saphenous veins

IMA: Internal Mammary Artery

- Prospective exposure-based sampling
- Technologists could use less than 30% decrease in tube current after subjective patient overweight estimation.
- Analysis included IMA grafts to the anterior territory and aortocoronary saphenous vein grafts to the right coronary artery.
- A total of 82 CABGs were evaluated; 240 graft segments (138 IMA and 102 saphenous vein segments) were assessable.
CT scanner specifications:
- 256-slice MDCT (Brilliance iCT, Philips Healthcare)
- Prospective ECG-gating
- Scanning voltage: 120kV
- Gantry speed rotation: 270ms
- Collimator: 2 x 128 x 0.625 mm

Scanning coverage extended above the origin of the IMA.

Noise, signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) measurements were obtained from the lumen of the proximal, body, and distal segments of the grafts.

Post-treatment reconstruction platform: Aquarius Intuition, Terarecon.
Grafts were separated in three segments to allow image quality evaluation:
- A. Proximal segment
- B. Body (middle segment)
- C. Distal segment

Measurements for the proximal and distal segments were taken within the first and last cm of observed graft, respectively. The choice of region-of-interest (ROI) positioning was done as to obtain a plane as parallel as possible to the short axis of the graft without overriding the vessel lumen.

For the body of the graft, ROI was chosen halfway from the proximal and distal anastomoses.
METHOD - IMAGE ANALYSIS

- Four quantitative criteria were used:
  - Attenuation Level and Noise Level;
    - Measured as mean attenuation level and associated standard deviation within ROIs respectively, both measured in Hounsfield Units (HU).
  - Signal-to-noise ratio (SNR)
  - Contrast-to-noise ratio (CNR)
    - Measured as:
      \[
      \text{Segment signal} - \text{Perivascular signal} \div \sqrt{1/2(\text{Segment noise}^2 + \text{Perivascular noise}^2)}
      \]
  - ROI positioned in the center of the lumen of the graft segment.
Method - Image analysis

• Noise Level:

• CNR:

\[
\text{Segment signal} - \text{Perivascular signal} \over \sqrt{1/2 (\text{Segment noise}^2 + \text{Perivascular noise}^2)}
\]

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RESULTS - PATIENT AND SCAN CHARACTERISTICS

<table>
<thead>
<tr>
<th>Base Parameters</th>
<th>Filtered back Projection</th>
<th>Iterative Reconstruction</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Men (Women)</td>
<td>23(2)</td>
<td>19(6)</td>
<td></td>
</tr>
<tr>
<td>Body Mass Index (BMI) (kg/m²)</td>
<td>26.61 ± 3.77</td>
<td>29.32 ± 3.75</td>
<td>p=0.014</td>
</tr>
<tr>
<td>Mean thoracic coverage (cm)</td>
<td>25.53 ± 2.33</td>
<td>25.03 ± 2.21</td>
<td>p=0.441</td>
</tr>
<tr>
<td>Mean metoprolol dose (mL)</td>
<td>71.15 ± 17.22</td>
<td>65 ± 12.91</td>
<td>p=0.399</td>
</tr>
<tr>
<td>Mean heart rate (bpm)</td>
<td>58.04 ± 6.70</td>
<td>55.92 ± 8.06</td>
<td>p=0.317</td>
</tr>
<tr>
<td>Mean current (mA)</td>
<td>880.24 ± 70.38</td>
<td>689.12 ± 123.71</td>
<td>p&lt;0.001</td>
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BMI between groups was found to be significantly superior in patients undergoing iterative reconstruction as opposed to FBP. Mean current used was significantly higher in the FBP group as opposed to the IR group by 21.71%.

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The effective radiation dose for the group of patients undergoing the IR protocol was 7.60 mSv, ie 23% lower when compared to the group undergoing the FBP protocol.
No significant difference was observed between attenuation levels for the standard dose protocol (and FBP) as opposed to the reduced dose protocol (and IR).
172 segments (72%) of graft segments presented a decrease in noise when using the low dose protocol with IR ($p \leq 0.040$). This decrease ranges from 20 to 29%.

No graft segment presented increased noise levels when using the low dose protocol with IR as opposed to FBP.
206 segments (86%) of graft segments presented an increase in SNR when using the low dose protocol with IR ($p \leq 0.010$), ranging from 28 to 63%. No segment presented a decrease in SNR when using the low dose protocol with IR.
172 segments (72%) of graft segments presented an increase in CNR when using the low dose protocol with IR ranging (p ≤ 0.030), ranging from 27 to 64%. No segment presented a decrease in CNR when using the low dose protocol with IR.
In this study, the use of a hybrid IR algorithm with a decreased current protocol enabled a 23% reduction of the effective dose (7.6 ± 1.3 mSv), compared with FBP and standard dose protocol (9.9 ± 1.4 mSv) (p < 0.001), with no loss in image quality.

In the IR patient group, we have chosen to reduce the current by a 30 % factor, except for patients who were overweight. It is worth noticing that other dose reduction strategies also exist, such as the use of a reduced kilovoltage, more aggressive current reduction, and size-dependent protocols. All of these strategies could also have been assessed, together with IR.

Image quality in our study was assessed using quantitative parameters (attenuation, noise, SNR, CNR). Although all CT examinations in this study were of diagnostic quality, visual assessment of image quality, using an ordinal scale, could also have been used.

It is interesting to note that improvements in image quality were observed in the IR and reduced current protocol patient group although the BMI was significantly higher in this group, in comparison to the FBP and standard dose protocol patient group.

Effective dose is proportional to the z-axis coverage. This explains the higher dose when CT is performed for CABG evaluation, in comparison to native coronary arteries. Z-axis coverage was similar in our two patient groups.
Our results show that iterative reconstruction enabled to decrease effective radiation dose by a 23 % factor in 256-MDCT angiography of CABGs while providing superior or similar image quality compared with filtered-back projection.