Coronary CT Angiography using iterative reconstruction vs. filtered back projection: evaluation of image quality

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Purpose

1. In 10 years, computed tomography coronary angiography (CTCA) has shifted from an investigational tool to clinical reality. Even though CT technologies are very advanced and widely available, a large body of evidence supporting the clinical role of CTCA is missing. The reason is that the speed of technological development has outpaced the ability of the scientific community to demonstrate the clinical utility of the technique [1].

2. A number of CT dose reduction techniques have been developed with the goal of preserving or improving image quality. Because the primary effect of reduced radiation dose is increased image noise, useful dose reduction techniques minimize the effect of reduced dose on noise. Currently used techniques to dose reduction and/or improve image quality technique is iterative reconstruction, a computationally complex method of image reconstruction is used to generate images with reduced noise [2-4]. This algorithm differs from the standard CT reconstruction algorithm of filtered backprojection (FBP). Unlike FBP, iterative reconstruction entails fewer assumptions regarding noise distribution within an image and operates with an iterative process of mathematic and statistical modeling to identify and selectively reduce noise [2-5]. This process improves the noise properties within the reconstructed images and maintains spatial resolution and image quality. The capability of reducing noise theoretically should allow tube current reduction and use of a higher noise index without degradation of image quality.

3. CTCA coronary atherosclerosis assessment is based upon the variable X-ray attenuation of the tissue components. However, several parameters, such as lumen attenuation, body mass index of the patient, convolution filtering, and contrast-to-noise ratio (CNR) of the images, are able to modify the attenuation values that are being used to define the composition of coronary plaque [6-20].

4. The purpose of this study was to compare image quality of iterative reconstruction algorithm (IRIS) vs. standard filtered back projection (FBP) reconstruction in CT Coronary Angiography (CTCA).

Methods and Materials

Study Population

Between October 2010 and August 2011 we prospectively enrolled 34 patients (20 men, 14 women; mean age±SD = 60.3±13.2 years) who underwent CT Coronary
Angiography (CTCA) for coronary artery evaluation (CAD). Only patients with sinus rhythm and able to maintain a breath-hold for at least 5 s were included. Patients with absolute contraindications to intravenous administration of iodinated contrast material (e.g., known allergy, kidney failure or thyroid disorders) were excluded. The ethics committee approved the study, and all patients provided informed (Table1).

**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.

**CT scan protocol**

The study was performed with a DSCT system with 128 (64×2×2) slices (Definition Flash, Siemens, Forchheim, Germany) [21, 22]. All patients underwent a scan without contrast enhancement for the quantification of coronary calcium followed by an angiography scan.

The following parameters were used for the angiography scans [22, 23]: 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, Germany). 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; Graph. 1). 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 [22, 24]. 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 [22, 25]. 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).
CT image reconstruction

For the study, additional reconstructions of the optimal diastolic phase were performed with the following parameters: effective slice thickness of 0.6 and 0.75 mm; reconstruction increment 0.4 mm; three different standard convolution kernels (B20-B26-B46; FBP) and three comparable convolution kernel with first-generation iterative reconstruction (I26-I46f; IRIS, Siemens, Germany) (Graph.2).

CT image evaluation

The reconstructed images were exported and transferred to a dedicated workstation with a cardiology software platform (SyngoVia, Siemens, Germany). To quantify the CT vascular attenuation value [expressed in Hounsfield units (HU)] and degree of attenuation obtained from the arrival of iodinated contrast material (enhancement), three regions of interest (ROIs) were placed in the ascending aorta (Ao), right (RCA) and left (IVA) coronary artery, respectively.

The signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were calculated as follows:

\[
\text{SNR} = \frac{\text{Vascular Density}}{\text{DS (air)}} \quad \text{and} \quad \text{CNR} = \frac{\text{Vascular Density} - \text{Muscle Density}}{\text{DS (air)}}
\]

where

- vascular density represents the average CT attenuation values measured in Ao, RCA and IVA
- muscle density represents the CT attenuation measured into the lateral wall of the left ventricle.

Statistical analysis

Data are reported as mean±standard deviation (SD). For data analysis we used commercially available software (MedCalc v9.2.1.0, Mariakerke, Belgium). The correlation between CT values, slice thickness and convolution kernels was tested using ANOVA test and Pearson's correlation coefficient. Differences were investigated with Student's T test (2 tails) for paired samples and a p<0.05 was considered as significant.
<table>
<thead>
<tr>
<th>Population</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>34</td>
</tr>
<tr>
<td>Age (years; mean±SD) 61.2±11.6</td>
<td>60.3±13.2</td>
</tr>
</tbody>
</table>

**Cardiovascular risk factors**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Count (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular risk factors</td>
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<tr>
<td>Hypertension</td>
<td>17 (50)</td>
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<tr>
<td>Hypercholesterolaemia</td>
<td>18 (53)</td>
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<tr>
<td>Diabetes</td>
<td>3 (9)</td>
</tr>
<tr>
<td>Cigarette smoking</td>
<td>53 (33)</td>
</tr>
<tr>
<td>Family history</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Obesity (BMI≥30 kg/m2)</td>
<td>9 (27)</td>
</tr>
</tbody>
</table>

Heart rate (bpm; mean±SD) 63.4±17.6

LVEF (%; mean±SD) 52.0±15.7

**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
Study Design. Every dataset were reconstructed with effective slice thickness of 0.6 and 0.75 mm; reconstruction increment 0.4 mm; three different standard convolution kernels (B20-B26-B46; FBP) and three comparable convolution kernel with first-generation iterative reconstruction (I26-I46f; IRIS, Siemens, Germany)

Fig. 1

Fig. 2: Study Design. Every dataset were reconstructed with effective slice thickness of 0.6 and 0.75 mm; reconstruction increment 0.4 mm; three different standard convolution kernels (B20-B26-B46; FBP) and three comparable convolution kernel with first-generation iterative reconstruction (I26-I46f; IRIS, Siemens, Germany)
Results

A total of 204 datasets, 102 obtained using FBP and 102 using IRIS. Table 2 shows the CT values measured on FBP and IRIS images for both slice thickness calculated. We didn't find significant differences between the CT attenuation values measured with different convolution kernels, except for the noise ($p<0.05$) (Graph3). Comparing FBP vs. IRIS, CT value of Ao was 458 vs 456HU, RCA 448 vs 446HU, IVA 444 vs 442HU and Noise 24 vs 19HU (Table3). Comparing slice thickness, ANOVA test showed significant differences in RCA (0.75I vs 0.6B, and vs 0.6I) and in Ao (0.6I vs B0.75, and vs 0.75I) ($p<0.05$) (Graph4). Lowest noise was found for IRIS using 0.6mm (17.1HU) (Table5). Compared to FBP, IRIS can provide S/N and C/N significantly higher with increasing kernel sharpness and (Graph5).

Images for this section:

Table 2: Attenuation values of various regions, expressed in Hounsfield units (HU), measured with different slice thickness and convolution filter B, dataset reconstruction using FBP kernel; I, dataset reconstruction using IRIS kernel; Ao, ascending aorta; RCA, right coronary artery; IVA, left coronary artery; SD, standard deviation
**Fig. 3:** Mean attenuation values of different convolution kernel, expressed in Hounsfield units (HU), based on various regions HU, Hounsfield Unit; B, dataset reconstruction using FBP kernel; I, dataset reconstruction using IRIS kernel; Ao, ascending aorta; RCA, right coronary artery; IVA, left coronary artery; SD, standard deviation

**Table 3:** Attenuation values of various regions, expressed in Hounsfield units (HU), measured with different convolution filter FBP, standard convolution kernel; IRIS, iterative reconstruction; Ao, ascending aorta; RCA, right coronary artery; IVA, left coronary artery; SD, standard deviation *p
**Fig. 4:** Mean attenuation values of various regions, expressed in Hounsfield units (HU), based on slice thickness and convolutional kernel HU, Hounsfield Unit; B, dataset reconstruction using FBP kernel; I, dataset reconstruction using IRIS kernel; Ao, ascending aorta; RCA, right coronary artery; IVA, left coronary artery; SD, standard deviation

**Table 4:** S/N and C/N values S/N, signal-to-noise ratio; C/N, contrast-to-noise ratio; B, FBP; I, IRIS
Fig. 5: S/N and C/N values. Compared to FBP, IRIS can provide S/N and C/N significantly higher with reducing kernel sharpness and slice thickness.
Conclusion

In CTCA, iterative reconstruction provide a significant higher image quality compared with the conventionally used FBP, thus enabling to increase diagnostic information.

References


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