Radiation Dose and Image Quality from Coronary Angiography in 320-Detector Row CT

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Abstract - Introduction: Coronary Computed Tomography Angiography examinations are increasing rapidly. NewComputed Tomography has been developed to improve image quality with the patient dose reduction. The purpose of this study is to evaluate radiation dose and image quality of Coronary Computed Tomography Angiography in patients using 320-detector row CT.

Methods: Forty-one patients referred for cardiac CT examinations at King Chulalongkorn Memorial Hospital were included in this study. All coronary computed tomographic angiography (CCTA) examinations were performed on the 320-detector row CT, Toshiba Aquilion One. Scanning protocol was investigated on dose estimates and image quality. Patients were scanned based on heart rate (HR) by HR < 65 bpm, use prospective gating 70-80% of R-R(1 heart beat), HR 66 – 70 bpm, use prospective gating 30 -80 % R-R(1 heart beat), HR 71 - 74 bpm, use prospective gating 30 -80 % R-R(2 heart beats) and HR > 75 bpm use retrospective with dose modulation. Scanning parameters, kVp, mAs, HR, BMI, CTDIvol(mGy) and DLP(mGy.cm), were recorded to study the factors affecting the image quality and patient dose. And mA and kVp setting depend on BMI of the patient. Effective dose is calculated from DLP using specific conversion factor. The image quality was evaluated in 4 vessels by two radiologists. Noise assessment was also studied quantitatively.

Results: The patient effective dose in prospective gating 70-80% was 3.6 ± 0.9 mSv, prospective gating 30-80% (1R-R) was 6.3 ± 1.9 mSv, and 30-80% (2R-R) was 10.8 ± 1.8 mSv and in retrospective with tube current modulation was 12.1 ± 7.7 mSv. Image noise was highest in PGT 70-80% 1R-R and decreased in RGT with tube current modulation, PGT 30-80% 1R-R and lowest in PGT 30-80% 2 R-R. And overall qualitative image quality was mostly good to excellent score.

Discussion: The heart rate, heart rate variability and disease of the patient are affecting in the radiation dose and image quality so the suitable acquisition protocol used could be necessary.

Conclusions: For cardiac CTA in 320-detector row, good to excellent image quality and patient dose reduction during CCTA are obtained especially in prospective technique when compared to earlier designed MDCTs using retrospective technique. The narrowing phase window width and single heart beat could be used for advantage of patient.

Key words - effective dose, dose length product, computed tomography dose index, heart rate, image quality

I. Introduction

Computed Tomography is a medical imaging modality which cross-sectional image of body has been obtained since its introduction into diagnostic radiology in early 1970s. Technical developments in CT result in the introduction of multi-detector computed tomography (MDCT) in 1999 [1]. At present, the numbers of detector slices have been developed until 320. As the number of detector slices increases and with faster gantry rotation speeds, the temporal resolution and spatial resolution are improved leading to better cardiac imaging.

Coronary artery disease (CAD) is an important cause of mortality and morbidity worldwide. According to WHO estimation in 2004, 16.7 million people die of cardiovascular diseases. Noninvasive method to evaluate the heart and its coronary arteries has long been desired by the medical community. The coronary arteries have been visualized directly by Coronary Computed Tomography Angiography (CCTA).

The aim of this study is to evaluate radiation dose and image quality of Coronary Computed Tomography Angiography in 320-Detector Row Computed Tomography in terms of Computed Tomography Dose Index (CTDI) and Dose-Length Product (DLP) leading to the calculation of
the effective dose and the image noise for the image quality.

II. MATERIALS AND METHODS

A. Quality Control (QC) of CT scanner TOSHIBA Aquilion ONE

The quality control of CT scanner was performed following the AAPM report No.39 (1993): specification and acceptance testing of CT scanner in the part of performance evaluation and ImPACT information leaflet 1: CT scanner acceptance testing version 1.02. The CTDI\textsubscript{vol} and DLP displayed on the monitor of the console of 320-detector row Toshiba Aquilion ONE were verified to make the confidence in using these values.

B. Coronary CTA patients

Coronary CTA patients at King Chulalongkorn Memorial Hospital with previous allergic reaction to iodinated CM, hemodynamic instability, pregnancy and Cr > 1.5 mg/dL will be excluded. First of all, the patient heart rate will be observed. Those whose heart rates are not in within desired limits (65 bpm) should be given beta blockers for slow down and stabilize it.

Scanning technique base on heart rate of the patient, HR ≤ 65 used Protocol 1: Prospective gating 70-80% of R-R (1 heart beat), HR 66 – 70 used Protocol 2: Prospective gating 30 -80% of R-R (1 heart beat), HR 71 - 74 used Protocol 3: Prospective gating 30 -80 % R-R (2 heart beat) and HR ≥ 75 used Protocol 4: Retrospective with dose modulation. The mA and kVp settings depend on the body mass index (BMI) of the patients. The settings were: BMI ≤ 20 kg/m², 120 kVp 300 mA, BMI 21-25 kg/m², 120 kVp 350 mA, BMI 26-30 kg/m² 120 kVp 400 mA and BMI ≥ 31kg/m² ,120 kVp 500 mA. The patient’s information, scanning parameters, CTDI\textsubscript{vol} and DLP were recorded.

C. Effective radiation dose estimation

The effective dose was calculated from DLP value multiplied by the conversion coefficient of 0.014 mSv/mGy.cm for chest [2].

D. Image quality analysis

The image quality was evaluated by two radiologists giving the score 4 to 1, where score 4 means excellent (Good vessel opacification with continuous course, without any motion artifacts), score 3 means good (Good vessel opacification, minor motion artifacts or discrete blurring of vessel margin and no stair-step artifacts), score 2 means fair (Visibly blurred vessel margin, clearly broader motion artifacts extending less than 5 mm from the vessel center, and stair-step artifacts < 25% of the vascular diameter) and score 1 means poor (Lack of vessel wall definition, presence of streak artifacts extending at least 5 mm from the center of the vessel and stair-step artifacts >25% of the vascular diameter). The quantitative image quality was assessed by the image noise. Image noise is defined as the SD of CT No. in a ROI (1cm²) placed in the aortic root at the level of the origin of the left main coronary artery.

III. RESULTS

A. Patient Information

Table. 1 Patient information in 4 protocols

<table>
<thead>
<tr>
<th>Protocol</th>
<th>N</th>
<th>Gender</th>
<th>BMI</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>(F/M) (kg/m²) (bpm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. PGT70-80%1RR</td>
<td>30</td>
<td>16/14</td>
<td>25.6</td>
<td>59.3</td>
</tr>
<tr>
<td>2. PGT30-80%1RR</td>
<td>3</td>
<td>0/3</td>
<td>21.8</td>
<td>69.7</td>
</tr>
<tr>
<td>3. PGT30-80%2RR</td>
<td>3</td>
<td>3/0</td>
<td>24.6</td>
<td>72.7</td>
</tr>
<tr>
<td>4. RGT with dose modulation</td>
<td>5</td>
<td>1/4</td>
<td>21.6</td>
<td>73.4</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>20/21</td>
<td>23.4</td>
<td>-</td>
</tr>
</tbody>
</table>

B. Radiation Dose
Table 2 CTDI<sub>vol</sub>, DLP and effective dose from coronary CTA of 41 patients in 4 protocols of various heart rates.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>CTDI&lt;sub&gt;vol&lt;/sub&gt; (mGy)</th>
<th>DLP (mGy.cm)</th>
<th>Effective dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PGT70-80%1RR</td>
<td>14.5</td>
<td>260.5</td>
<td>3.6±0.9</td>
</tr>
<tr>
<td>2. PGT30-80%1RR</td>
<td>31.1</td>
<td>448.2</td>
<td>6.3±1.9</td>
</tr>
<tr>
<td>3. PGT30-80%2RR</td>
<td>46.7</td>
<td>767.0</td>
<td>10.8±1.8</td>
</tr>
<tr>
<td>4. RGT with dose modulation</td>
<td>49.3</td>
<td>868.0</td>
<td>12.1±7.7</td>
</tr>
</tbody>
</table>

Fig. 1 Effective dose from coronary CTA is plotted against 41 patients of 4 protocols

C. Image quality

Qualitative image quality

Table 3 Overall Image scoring

<table>
<thead>
<tr>
<th>Score</th>
<th>RCA</th>
<th>LMA</th>
<th>LAD</th>
<th>LCX</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 = Excellent</td>
<td>18(43.9%)</td>
<td>25(60.1%)</td>
<td>18(43.9%)</td>
<td>17(41.5%)</td>
</tr>
<tr>
<td>3 = Good</td>
<td>16(39.0%)</td>
<td>16(39.0%)</td>
<td>21(51.2%)</td>
<td>18(43.9%)</td>
</tr>
<tr>
<td>2 = Fair</td>
<td>7(17.1%)</td>
<td>0(0%)</td>
<td>2(4.9%)</td>
<td>6(14.6%)</td>
</tr>
<tr>
<td>1 = Poor</td>
<td>0(0%)</td>
<td>0(0%)</td>
<td>0(0%)</td>
<td>0(0%)</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
</tr>
</tbody>
</table>

* Weighted Kappa = 0.652
(www.medcalc.org/manual/kappa.php)

IV. DISCUSSION

41 consecutive patients were scanned using different protocols according to the heart rates. The patients were controlled to keep low heart rate so 30 patients used protocol PGT 70-80% 1R-R interval acquisition. Some patient with the heart rate less than 65 bpm RGT was selected because of the heart rate variability so cannot use the PGT.
CTDI\_vol was 14.5 mGy in PGT 70-80\% 1R-R which was lowest and the highest was 49.3 mGy in RGT even though the tube current modulation had been selected. In PGT, the CTDI\_vol increased from 14.5 to 31.1 and 46.7 mGy in phase window 70-80\% 1R-R, 30-80\% 1R-R and 30-80\% 2R-R, respectively. The effective dose was lowest in PGT 70-80\% 1R-R of 3.6 ± 0.9 mSv and increases in PGT 30-80\% 1R-R of 6.3 ± 1.9 mSv, PGT 30-80\% 2 R-R of 10.8 ± 1.8 mSv and highest in RGT with tube current modulation of 12.1 ± 7.7 mSv. The highest dose in case no. 4 of the RGT with tube current modulation was 25.1 mSv because of 3 R-R.

In the part of quantitative image quality, image noise in PGT 70-80\% 1R-R was 23.6 ± 3.8 HU which was highest and decreased in PGT 30-0\% 1R-R to 17.8 ± 1.1 HU, and lowest in PGT 30-80\% 2R-R of 14.4 ± 2.8 HU. The image noise in RGT with tube current modulation was 21.5 ± 6.7 HU.

For overall qualitative image scored by two radiologists (weighted kappa value = 0.652) show the good agreement. For RCA, excellent 43.9\%, good 39.0\%, fair 17.0\% and poor 0\% score were recorded. LMA, excellent 60.1\%, good 39.0\%, fair and poor 0\% score, LAD excellent 43.9\%, good 51.2\%, fair 4.9\% and poor 0\% score. LCX, excellent 41.5\%, good 43.9\%, fair 14.6\% and poor 0\% score.

In comparison with another studies [3], [4], [5] with nearby acquisition protocol, the effective dose in this study is mostly lower than the others because of the less phase window width. Steigner ML, el al [6] studied the narrowing phase window width in prospectively ECG-gated single heart beat in 320-detector row coronary CT angiography, found that the phase window width of 10\% reduce patient radiation and yield diagnostic images in more than 90\% of patients.

V. CONCLUSIONS

Coronary Angiography studied by 320-detector row computed tomography, the effective dose in PGT 70-80\% 1R-R was lowest, 3.6 ± 0.9 mSv, in PGT 30-80\% 1R-R and 2R-R and 6.3 ± 1.9 and 10.8 ± 1.8 mSv, respectively. In RGT with tube current modulation, the effective dose was highest at 12.1 ± 7.7 mSv.

Image noise was highest in PGT 70-80\% 1R-R and decreased in RGT with tube current modulation, PGT 30-80\% 1R-R and lowest in PGT 30-80\% 2 R-R. Overall qualitative image quality was mostly good to excellent score.

In conclusion, this study shows that in patients with low heart rate, PGT 70-80\% 1 R-R in 320 detector-row CT, lower radiation dose and good to excellent image quality could be obtained because of the narrowing phase window width and single heart beat. In higher heart rate patient, more phase window and more heart beat could be used. In addition, the RGT with tube current modulation, the effective dose was higher than PGT but lower than RGT with full dose exposure so can be used in higher heart rate for good diagnostic.

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REFERENCES


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