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Influence of Heart Rate on Image Quality and Radiation Dose Exposure in Coronary CT Angiography

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Conflicts of interest are listed at the end of this article.

See also the editorial by Schoppf and Decke in this issue.

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P < .05 was considered indicative of a statistically significant difference.

The diagnostic value of coronary CT angiography (CTA) strongly depends on image quality, and radiation dose should be as low as reasonably achievable. Heart rate was identified as an independent predictor for coronary CTA image quality and radiation exposure (1,2). However, scanner and protocol improvements may bring to question the importance of heart rate control, and the optimal heart rate for patients undergoing coronary CTA is currently unclear. In this subanalysis of the Prospective Multicenter Registry on Radiation Dose Estimates of Cardiac CT Angiography in Daily Practice, or PROTECTION VI (3,4), we aimed to identify the optimal heart rate in coronary CTA allowing for best image quality and radiation dose reduction.

Materials and Methods

We consecutively included the first 50% of coronary CTA examinations from each PROTECTION VI study site enrolled between March and December 2017 (clinical trial registration number NCT02996903). All study sites were in control of their CT protocols. Images from CTA were evaluated in a core laboratory by a blinded CTA scan reader with 5 years of experience. A second reader, also with 5 years of experience, re-evaluated 20% of CTA examinations from each PROTECTION-VI study site. The median image quality score was 3.5 (IQR, 3.0–3.75), the median signal-to-noise ratio was 14 (IQR, 11–18), and the median contrast-to-noise ratio was 11 (IQR, 8–15). The median heart rate was 60 beats per minute (IQR, 55–66 beats per minute; 1798 patients [94%] were in sinus rhythm (unspecified in 12 patients), and 1370 patients [72%] received beta blocker therapy before undergoing coronary CTA. The median image quality score was 3.5 (IQR, 3.0–3.75), the median signal-to-noise ratio was 14 (IQR, 11–18), and the median contrast-to-noise ratio was 11 (IQR, 8–15). The median dose-length product was 170 mGy · cm (IQR, 99–310 mGy · cm). The CT scan mode was associated with radiation exposure (retrospective helical: 376 mGy · cm; prospective axial: 107 mGy · cm; prospective helical: 46 mGy · cm; P < .001).

Patients were grouped by heart rates in intervals of five beats per minute (≥45 beats per minute: 59 patients; 46–50 beats per minute: 158 patients; 51–55 beats per minute: 362 patients; 56–60 beats per minute: 473 patients; 61–65 beats per minute: 358 patients; 66–70 beats per minute: 249 patients; 71–75 beats per minute: 101 patients; >75 beats per minute: 149 patients). The median image quality score was higher in patients with a heart rate below 60 beats per minute (image quality score, ≥3.5) than in those with a heart rate above 60 beats per minute (Fig 2, A) (all P < .01). Linear regression analysis demonstrated an improvement of image quality with heart rate reduction (effect on image quality score: +0.18 per 10–beat per minute decrease in heart rate, P < .001), and the effect was confirmed in a multivariable model that included various CT scanner specifications (Table). The median image quality score was 3.5 (IQR, 3.0–3.75) in patients with a heart rate below 60 beats per minute and 3.5 (IQR, 3.0–3.75) in those with a heart rate above 60 beats per minute (Fig 2, B, all P < .01). Linear regression analysis demonstrated an improvement of image quality with heart rate reduction (Fig 2, B) (all P < .01). Linear regression analysis demonstrated an improvement of image quality with heart rate reduction (effect on image quality score: +0.18 per 10–beat per minute decrease in heart rate, P < .001), and the effect was confirmed in a multivariable model that included various CT scanner specifications (Table).
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**Figure 1:** CT angiographs show representative grading of the image quality for the right coronary artery. A, Grade 1 (nondiagnostic); B, grade 2 (adequate); C, grade 3 (good); D, grade 4 (excellent).

**Coronary CTA image quality and radiation dose exposure by heart rate**

![Graph showing image quality and radiation dose by heart rate](image)

**Discussion**

The results from this international, multivendor, real-world analysis confirm the notion that heart rate has significant influence on image quality in coronary CT angiography (CTA). The results suggest that cardiologists and radiologists should aim for a lower patient heart rate to obtain the best image quality and simultaneously allow for lower radiation dose in coronary CTA imaging. Therefore, the use of beta blockers should be considered in the absence of contraindications for heart rate control.
## Effect of Heart Rate Reduction and CT Scanner Specifications on Image Quality of Coronary CT Angiograms

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Univariable Analysis</th>
<th>Multivariable Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Effect</td>
<td>P Value</td>
</tr>
<tr>
<td>Heart rate (per 10-beat/min decrease)</td>
<td>0.18 (0.13, 0.23)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>CT gantry rotation time (≤ 280 msec)</td>
<td>0.31 (0.16, 0.46)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>CT detector width (reference: 128–192 sections)</td>
<td>≤ 64 sections: -0.56 (-0.85, -0.26) &lt;.001*</td>
<td>-0.21 (-0.60, 0.17) .28</td>
</tr>
<tr>
<td></td>
<td>256–320 sections: -0.16 (-0.33, 0.01) .07</td>
<td>-0.40 (-1.00, 0.20) .19</td>
</tr>
<tr>
<td>CT scan mode (reference: retrospective helical)</td>
<td>Prospective axial: 0.07 (-0.14, 0.28) .53</td>
<td>-0.06 (-0.21, 0.09) .43</td>
</tr>
<tr>
<td></td>
<td>Prospective helical: 0.36 (0.12, 0.59) &lt;.05*</td>
<td>0.18 (0.03, 0.32) .10</td>
</tr>
<tr>
<td>CT manufacturer (reference: GE Healthcare)</td>
<td>Siemens: 0.22 (0.03, 0.42) &lt;.05*</td>
<td>-0.10 (-0.67, 0.47) .73</td>
</tr>
<tr>
<td></td>
<td>Philips: -0.01 (-0.18, 0.16) .95</td>
<td>0.02 (-0.16, 0.36) .82</td>
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<tr>
<td></td>
<td>Canon: -0.02 (-0.18, 0.18) .89</td>
<td>-0.02 (-0.23, 0.19) .85</td>
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</tbody>
</table>

Note.—Unless otherwise specified, data are the effect on image quality score, with 95% CIs in parentheses.

* Statistically significant difference.