Triple Rule-out using 320-row-detector volume MDCT: A comparison of the wide volume and helical modes

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Purpose

Acute-onset chest pain is one of the most frequent symptoms encountered in the emergency room, and accounts for 5-20% of visits to emergency departments [1]. Triple rule-out (TRO) computed tomography (CT) can provide a cost-effective means of evaluating coronary arteries, the aorta, and pulmonary arteries in patients with acute chest pain [2, 3]. However, the longer anatomical coverage required than coronary CT angiography (CTA) and requires sufficient and simultaneous opacification of pulmonary arteries, coronary arteries, and aorta, which requires larger radiation exposures and large doses of contrast medium [2-4].

To date, the largest z-axis coverage (320-detector row) CT allows 16 cm z-axis coverage, and thus, the whole chest CTA scan can be archived with two axial volume scan acquisitions ("wide volume scan"), which reduces the duration of CT acquisition and radiation exposure.

Therefore, we undertook this study to investigate the image quality and radiation dose required TRO CT using a wide volume scan mode and to compare this with helical mode on the same CT system.
Methods and Materials

Patients

64 patients (47 males and 17 females; age range, 19-85 years; mean age, 60.1±15.1 years) were enrolled.

- Inclusion criteria: the presence of an acute (but noncritical) pain, clinical suspicion of pulmonary embolism, aortic dissection, low to intermediate risk of coronary artery disease (CAD)

- Exclusion criteria: high risk for CAD, a history of allergic reaction to contrast material, and renal insufficiency.

The patients were randomly allocated to two different TRO protocols:

- 31 patients: wide volume scan (non-spiral) mode (group 1)
- 33 patients: 160-detector row helical mode (group 2; the control group)

Image acquisition and post-processing

All 64 patients underwent TRO CT on the 320-detector row scanner with 100-120kV, 400-550mA based on body mass index (BMI) and gantry rotation time; 350 msec.

- Contrast media: Injections of iodinated contrast material were acquired using a biphasic injection protocol with a total iodinated contrast medium volume of 65-100ml (median amount, 70ml), flow rate; 4ml/sec

- Scan coverage: the entire thoracic aorta from the clavicle to the base of the heart.

*Wide volume (non-spiral) mode: group 1

Consisted of two data acquisitions with a 4-5 sec interval between acquisitions (a machine limitation due to ECG-gating). The detector width was set at 14-16 cm to cover half of the
entire thorax. The resulting thin-slice partial volume data sets were automatically stitched immediately after reconstruction for chest examination. A second dataset (lower portion of chest) was separately reconstructed for coronary CTA (Fig. 1 on page 6).

* 160-detector row helical mode: Group 2

The detector width was set at 8 cm and 0.17-0.25 pitch. The resulting datasets were reconstructed for chest CTA and coronary CTA, respectively.

When the heart rate was sufficiently slow (#65 beat/min), CT scans were obtained by prospectively triggered, data acquisition at 70~80% of the R-R interval (groups 1A and 2A). The examinations of other patients (group 1B and 2B) were performed by retrospective data acquisition with ECG-based tube current modulation. In some patients with rapid, irregular heart beats, images were produced by multisegment reconstruction with two beats.

Axial images of the whole thorax scan range were reconstructed from 75% cardiac phase at a slice thickness of 3mm. Heart regions were additionally reconstructed in a field of view adapted to heart size at a slice thickness of 0.5mm, and an initial interpretation was performed using reconstructed images from the 75% cardiac phase or the automatically suggested 'best phase (msec)'. Additional images were reconstructed patients with a rapid heart beats as needed.

**Analysis of image noise and quality**

The attenuations (HU) of main pulmonary artery, ascending aorta, and coronary arteries (proximal left anterior descending artery, proximal left circumflex artery and proximal right coronary artery) on each axial image were measured.

Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) in proximal RCAs were calculated as previously published [7, 8]. Vessel contrast was calculated as the difference between the mean attenuation of contrast medium (in HU) in contrast-enhanced vessel lumen and the mean attenuation (in HU) in adjacent perivascular tissue. Image noise was defined as the SD of the attenuation value of the ROI placed in the aortic root.

\[
\text{SNR} = \frac{\text{Vessel density (HU}}{\text{ascending aorta}}} / \text{Image noise (SD}}{\text{ascending aorta}}
\]

\[
\text{CNR} = \frac{\text{Vessel contrast (HU}}{\text{RCA}} - \text{HU}}{\text{perivascular tissue}} / \text{Image noise (SD}}{\text{ascending aorta}}
\]
To determination image qualities, a subjective overall patient-based image quality score of 1-3 was assigned to the coronary CT angiography (CTA) and chest CTA in each study. Quality scores were defined as follows:

1 = excellent, no motion artifact and excellent visualization of vessel lumen;
2 = good, some artifact, but still sufficient for diagnostic purposes;
3 = poor; massive motion artifacts, inadequate for diagnosis.

**Estimation of radiation dose**

The products of CT dose index (CTDIvol) and scan lengths were calculated, and effective doses (mSv) were calculated as described by the European Working Group guidelines regarding Quality Criteria for CT using the dose-length product and a conversion coefficient (k=0.017mSv/[mGy·cm]) [9].

**Statistics**

TRO CT in 160-detector row helical mode was defined as the standard protocol. All estimated data (radiation dose used during each examination, HU, SNR and CNR) were expressed as means ± standard deviations. PASW® Statistics 18 (SPSS Inc., Chicago, Illinois) was used for the statistical analysis. Differences between groups were examined using independent t tests for continuous variables and the $\chi^2$ test for categorical variables, and $P$-values of less than 0.05 were considered statistically significant.
Fig. 1: Schematic showing wide volume scan method. Whole chest CT scan archived with two acquisitions of axial volume scan that were automatically stitched immediately after reconstruction than the second data (lower portion of chest) were separately reconstructed for coronary angiography.

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Results

Patients

No significant difference in age, gender distribution, BMI, or heart rate was evident between groups 1 and 2 (Table 1 on page 9).

Image quality

The mean attenuation of main pulmonary trunk was higher in group 1 than in group 2 ($P = 0.04$) and that of other vessels (ascending aorta and coronary arteries) were not significantly different in the two groups.

There were no significant differences between group 1 and 2, respectively for Image noise (SD of ascending aorta), SNR and CNR (Table 2 on page 9).

Assessment of subjective image quality revealed an overall diagnostic image quality (score 1 and 2) of 93.7% for both chest CTA and coronary CTA (Table 3 on page 10).

- In chest CTA, the group 2 showed larger image number with excellent quality (score 1; 67.7% vs 87.9%, $P=0.09$), but no significant difference with a range of diagnostic image quality (score 1+2; 93.5% vs. 93.9%) and poor image quality (score 3; 6.5% vs. 6.1%).

- In coronary CTA, there were no significant differences with excellent quality (score 1; 77.4% vs. 75.8%), but poor image quality (score 3) were only observed in group 2 (4 of 33 images, 12.1%, $P=0.09$).

Two patients of each group showed poor quality (score 3) of chest CTA, due to failed breath-hold during the examinations. The chest CTA of two patients in group 1B showed stair-step artifact between two axial volume scans, but coronary CTA was still diagnostic quality (Fig. 2 on page 10). The Chest CTA in two patients in group 2B showed multiple stair-step artifacts, and in these patients, coronary CTA image quality was also non-diagnostic (Fig. 3 on page 11).

Radiation dose

The wide volume scan mode TRO CT protocol required a lower radiation dose than the 160-rain standard helical protocol (Table 4 on page 10). Mean scan length was greater in group 1 than in group 2 (26.3±20.5cm vs 23.8±3.3cm, $P=0.0005$), but the average
effective dose was significantly lower in group 1 than in group 2 (9.7±5.1 mSv vs 16.1±6.0 mSv, P<0.0001).

Two patients of group 1B (wide volume retrospective mode) showed rapid, irregular heart beats despite beta blocker administration (86-92 and 75-86 bpm, respectively), and thus, images were obtained with multisegment reconstruction method using a 2-beats (Fig. 4 on page 11). In these patients, images were diagnostic, but large amount of effective doses were produced (23.2 mSv and 25.1 mSv, respectively).
### Table 1: General characteristics of the each group patients.

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<table>
<thead>
<tr>
<th></th>
<th>Wide volume mode (Group 1)</th>
<th>Helical mode (Group 2)</th>
<th>Total (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>19</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>Sex (Male/ Female)</td>
<td>14/5</td>
<td>8/4</td>
<td>22/9</td>
</tr>
<tr>
<td>Age (years)</td>
<td>60 ± 12.3</td>
<td>60 ± 18.9</td>
<td>60 ± 14.9</td>
</tr>
<tr>
<td></td>
<td>(0.33)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.9 ± 2.1</td>
<td>22.4 ± 2.0</td>
<td>22.7 ± 2.0</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>59 ± 10.6</td>
<td>68 ± 12</td>
<td>62 ± 12.1</td>
</tr>
</tbody>
</table>

Note: Values are presented as mean ± SD. BMI indicates Body mass index; 1A, prospective wide volume mode; 1B, retrospective wide volume mode; 2A, prospective helical mode; 2B, retrospective helical mode

### Table 2: Comparison of between two acquisition modes for mean attenuations (HU) of each vessel, background noise (HU), signal to noise ratios (SNR) and contrast to noise ratios (CNR).

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<table>
<thead>
<tr>
<th>Density of vessels (HU)</th>
<th>Wide volume mode (Group 1, N=31)</th>
<th>Helical mode (Group 2, N=33)</th>
<th>Total (N=64)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary trunk</td>
<td>379.2 ± 142.1</td>
<td>312.6 ± 104.6</td>
<td>344.3 ± 127.3</td>
<td>0.04</td>
</tr>
<tr>
<td>Ascending aorta</td>
<td>451.8 ± 95.3</td>
<td>453.9 ± 94.4</td>
<td>452.9 ± 94.0</td>
<td>0.93</td>
</tr>
<tr>
<td>LAD</td>
<td>435.2 ± 104.7</td>
<td>410.8 ± 78.1</td>
<td>423.0 ± 92.3</td>
<td>0.35</td>
</tr>
<tr>
<td>RCA</td>
<td>444.8 ± 121.0</td>
<td>446.8 ± 57.6</td>
<td>445.8 ± 92.6</td>
<td>0.93</td>
</tr>
<tr>
<td>LCX</td>
<td>439.5 ± 113.8</td>
<td>422.6 ± 99.8</td>
<td>431.2 ± 106.5</td>
<td>0.58</td>
</tr>
<tr>
<td>Background noise (HU)</td>
<td>32.8 ± 7.9</td>
<td>33.5 ± 8.7</td>
<td>33.2 ± 8.2</td>
<td>0.74</td>
</tr>
<tr>
<td>SNR</td>
<td>13.6 ± 4.4</td>
<td>14.1 ± 4.9</td>
<td>13.9 ± 4.7</td>
<td>0.70</td>
</tr>
<tr>
<td>CNR</td>
<td>16.8 ± 4.5</td>
<td>16.5 ± 4.6</td>
<td>16.7 ± 4.5</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Note: Values are presented as mean ± SD. LAD indicates left anterior descending artery; RCA, Right coronary artery; LCX, Left circumflex artery; Background noise means SD of aortic root; SNR, Signal to noise ratios; CNR, Contrast to noise ratios.
Table 3: Qualitative assessment of image quality for chest CTA and coronary CTA on each groups.

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<table>
<thead>
<tr>
<th></th>
<th>Wide volume mode (Group1, N=31)</th>
<th>Helical mode (Group 2, N=33)</th>
<th>Total (N=64)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chest CTA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent (1)</td>
<td>21/31 (67.7%)</td>
<td>29/33 (87.9%)</td>
<td>50/64 (78.1%)</td>
</tr>
<tr>
<td>Diagnostic (1+2)</td>
<td>29/31 (93.5%)</td>
<td>31/33 (93.9%)</td>
<td>60/64 (93.7%)</td>
</tr>
<tr>
<td>Poor (3)</td>
<td>2/31 (6.5%)</td>
<td>2/33 (6.1%)</td>
<td>4/64 (6.3%)</td>
</tr>
<tr>
<td><strong>Coronary CTA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent (1)</td>
<td>24/31 (77.4%)</td>
<td>25/33 (75.8%)</td>
<td>49/64 (76.6%)</td>
</tr>
<tr>
<td>Diagnostic (1+2)</td>
<td>31/31 (100%)</td>
<td>29/33 (87.9%)</td>
<td>60/64 (93.7%)</td>
</tr>
<tr>
<td>Poor (3)</td>
<td>0/31 (0%)</td>
<td>4/33 (12.1%)</td>
<td>4/64 (6.3%)</td>
</tr>
</tbody>
</table>

Note: Values are presented as number of cases (%). Images score: 1 = excellent, no motion artifact, 2 = good, some artifact, but still sufficient for diagnosis, and 3 = poor, inadequate for diagnosis.

Table 4: Comparison of radiation doses between each groups.

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<table>
<thead>
<tr>
<th></th>
<th>Wide volume mode (Group 1, N=31)</th>
<th>Helical mode (Group 2, N=33)</th>
<th>Total (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exposure time (sec)</strong></td>
<td>0.76 ± 0.2</td>
<td>3.14 ± 0.9</td>
<td>1.68 ± 1.3</td>
</tr>
<tr>
<td><strong>CTDInvol (mGy)</strong></td>
<td>18.0 ± 4.0</td>
<td>38.9 ± 15.0</td>
<td>26.1 ± 14.1</td>
</tr>
<tr>
<td><strong>Scan length (cm)</strong></td>
<td>26.4 ± 2.0</td>
<td>26.3 ± 2.1</td>
<td>26.3 ± 20.5</td>
</tr>
<tr>
<td><strong>Effective dose (mSv)</strong></td>
<td>6.8 ± 1.7</td>
<td>14.4 ± 5.2</td>
<td>9.7 ± 5.1</td>
</tr>
</tbody>
</table>

Note: Values are presented as mean ± SD, 1A indicates prospective wide mode volume; 1B, retrospective wide volume mode; 2A, prospective helical mode; 2B, retrospective helical mode.
**Fig. 2:** A 40-year-old man (in group 1B) underwent wide volume method TRO CT. The chest CTA showed stair-step artifact (arrow in a) between the two volume scans, but the image quality of coronary CTA was diagnostic.

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**Fig. 3:** 35-year-old man (in group 2B) underwent retrospective helical method TRO CT. The chest CTA showed multiple stair-step artifacts (arrows in B) at whole chest and coronary CTA was also non-diagnostic.

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**Fig. 4:** A case of group 1B underwent TRO-CT with multisegment reconstruction method. A 88-year-old man with rapid, irregular heart beats (86-92 bpm). Both chest CTA and coronary CTA images were diagnostic quality (Exposure time, 4.33 sec; CTDIvol, 62.2 mGy; scan length, 26.4 cm; effective doses, 23.2 mSv).

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Conclusion

The use of wide volume mode reduced overall effective radiation doses by about 60% and resulted in nearly same or partially better opacification and image quality for triple rule-out as compared with helical mode.
References


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