Evaluation of 64-slice MDCT in the real world of cardiology: A comparison with conventional coronary angiography

Marc Sirol\textsuperscript{a,b,*}, Javier Sanz\textsuperscript{c}, Patrick Henry\textsuperscript{a}, Roland Rymer\textsuperscript{b}, Alexander Leber\textsuperscript{d}

\textsuperscript{a} Cardiology department, Lariboisière hospital, AP-HP, 2, rue Ambroise-Paré, 75010 Paris, France
\textsuperscript{b} Radiology department, Lariboisière hospital, AP-HP, 2, rue Ambroise-Paré, Paris, France
\textsuperscript{c} The Zena and Michael A. Wiener cardiovascular institute, the Marie-José and Henry R. Kravis cardiovascular health center, Mount Sinai School of Medicine, New York, USA
\textsuperscript{d} Department of clinical cardiology and radiology, Ludwig-Maximilians-University, Munich, Germany

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Summary Multi-detector row computed tomography (MDCT) offers an alternative to diagnostic coronary angiography for visualizing coronary arteries. The major limitation of recently published studies, aside from being monocentric in nature and the low number of patients included, is the selection of patients. These studies do not provide any answers for patients who are seen daily in cardiology consultation. The purpose of our study was to determine the diagnostic accuracy of MDCT as compared with coronary angiography on a population of average patients who were not selected.

Materials and methods. — Forty-eight patients with suspected coronary artery disease successively underwent 64-slice MDCT followed by coronary angiography with 24 to 48 hours. The diagnostic accuracy detection of significant coronary stenoses (greater than 50% stenoses in arteries greater than 1.5 mm in diameter) was determined and the two techniques were compared.
Results. — Nearly half of the patients included had known histories of coronary artery disease \((N = 24; 50\%)\). The sensitivity, specificity, positive and negative predictive value, and the diagnostic accuracy of MDCT in detecting significant coronary stenoses were 81.2, 98.2, 87.5, 97 and 93.9\% in per-segment evaluation. During the per-patient evaluation, the efficacy of MDCT dropped with the values being 77.4, 92.3, 87.8, 79.2 and 81.6\% respectively.

Conclusion. — The use of 64-slice MDCT results in excellent diagnostic accuracy and in an increased negative predictive value for detecting significant coronary stenoses in per-segment analysis. Per-patient analysis significantly reduced the value of the scan, demonstrating that patients with a high probability of coronary artery disease do not benefit from this type of non-invasive approach.

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greater than 1.3 g/dL (or > 150 μmol/L), clinical instability (unstable angina pectoris or decompensated cardiac insufficiency), contra-indication to beta blockers (including history of bronchial hyperactivity, high-degree auriculoventricular blockage, allergy, or known left ventricular ejection fraction of < 35%), obesity (weight of 200 kg or greater).

**Technique**

All of the exams were performed using a multislice scanner (Sensation 64, Siemens, Germany) with image reconstruction retrospectively synchronized to the ECG. The standard acquisition protocol included a rotation time of 330 minutes, a slice thickness of 0.4 mm and a contrast product injection from 80 cc to 120 cc using Visipaque 320. The injection flow rate was 5 cc per second. The acquisition delay was computed automatically by placing a region of interest at the ascending aorta, with an automatic start threshold of 150 Hounsfield units (HU). The images were acquired at 120 kilovolts (kV) and 500—800 milli-amperes per second (mA/s) with dose modulation (ECG-pulsing, Siemens). Acquisition time was between eight and 15 seconds depending on the patient’s anatomy, coverage and extent of the anatomical region explored (the field of acquisition was extended to the sub-clavicle arteries when evaluating a specific vascular region, such as the iliac arteries). Nitrate derivatives (trinitrile simple Laleuf 0.15 mg orally) were administered systematically just prior to performing the scan. A beta-blocker was administered if HR > 70 per minute (metoprolol in the form of intravenous bolus of 5 mg every 5 minutes up to a maximum dose of 15 mg). In case of broncho-pulmonary disease or allergy, an intravenous injection of diltiazem was administered as follows: Initial bolus of 0.2 mg/kg followed by a second bolus of 0.3 mg/kg. For essentially practical reasons, we did not use oral beta-blockers since they significantly prolong the time of the patient’s stay following the exam [7].

**Image reconstruction**

A first set of images was systematically reconstructed at 70% of the RR interval (thus, the images are obtained during the diastole) using a slice thickness of 0.6 mm with an increment of 0.3 mm per slice with a medium soft filter in the mediastinal view. The images were immediately reconstructed in 3-dimensions and the image quality was estimated from axial, frontal and sagittal views. If there were kinetic artifacts due to heart movements, additional image reconstructions were performed at different times in the cardiac cycle. The series with the fewest movement artifacts was selected for final analysis. If there was calcification or a coronary stent present, a series of additional images was reconstructed with a high-resolution filter in order to minimize the partial volume effects. The presence of severe calcification or intracoronary stents was not held as source criteria for poor image quality even if it impeded visualization of coronary stenoses and reduced the diagnostic performance of the test.

Two experienced readers (a radiologist and a cardiologist) read the scans blinded to coronary angiogram results. If there was no agreement, an agreement was finally found between the two readers on the significance of the stenosis.

Patients whose scans presented respiratory movement or other artifacts were excluded from the final analysis.

**Conventional angiography**

Coronary angiography was performed by retrograde catheterization in the conventional manner. Multiple views allowed obtaining a conventional angiography of the three principal arteries, which was performed in the standard manner before and after injecting nitrate derivatives [8]. The degree of coronary stenosis was evaluated by quantitative measurement (quantitative coronary angiography — QCA). The mean luminal diameter of the coronary arteries, as well as the degree of stenosis was determined on two projections, by an independent researcher, without having knowledge of the results of the scan.

**Statistical analysis**

The continuous variables are expressed as an average ± the standard deviation (SD), with the categorical variables being expressed as percentages. Sensitivity, specificity, negative and positive predictive value and diagnostic accuracy of the test were calculated to determine the presence of significant (> 50%) or severe (> 75%) stenoses on MDCT scanning. Analysis was performed per segment, artery and patient, including and excluding the segments that could not be evaluated on scanning.

The agreement between the two diagnostic techniques for classifying the severity of coronary lesions was evaluated using the statistical coefficient kappa (K) with a 95% confidence interval, and the correlation with the Spearman test (r). A value of K < 0.75 indicates excellent agreement between the two techniques and 0.40 < K < 0.75 indicates good agreement [9]. A value of P < 0.05 was considered to be statistically significant. All calculations were performed using Statview 5.0 produced by SAS Institute, Inc.

**Results**

Opacification of the coronary arteries was correct in all of the patients on the scans except for one which was due to poor synchronization between acquisition of the images and injection of the contrast media. This patient was excluded from the final analysis. Patients (N = 47) were included in the study as a result of a positive or uncertain stress test (N = 32) or due to clinical symptoms (N = 15), mainly of abnormal chest pain. The mean age inclusion was 57.8 ± 12.8 years (ranging from 27 to 85 years), of which 35 were men (74%). Twenty-four patients (50% of the study population) had a history of ischemic heart disease. Nine patients (19.1%) had an history of myocardial infarction (MI). Eleven patients (23.4%) had an implant or more than one coronary stent, and six patients (12.7%) had histories of aorticcoronary bypass surgery. During MDCT, the mean heart rate was 61.3 ± 7.5 bpm, ranging from 45 to 80 bpm. The heart rate was reduced in 28 patients (59.5%) before 64-slice MDCT scanning was performed either by injecting beta-blockers (N = 25; mean dose of metoprolol 12.1 ± 6 mg) or diltiazem (N = 3; 10 mg — patients with bronchial asthma).
Figure 1. Examples of non-invasive angiographs using 64-slice MDCT (right column) and corresponding images obtained with conventional coronary angiography (left column). A. Normal right coronary artery. B. Image obtained on MDCT allows to rule out significant stenosis. C. Total occlusion of the proximal segment of the right coronary artery (Arrow). The second panel shows retrograde filling through the collaterals of the distal and median segments after selective injection of contrast for the common section. D. The same lesion is visualized on MDCT by a hypodensity (Arrow). This stenosis was wrongly classified as “severe” and not as an “occlusion” due to the presence of contrast media distally.

Coronary angiography highlighted significant coronary stenoses (stenosis > 50%) in 25 patients (53.2%). Monotruncular lesions were less frequent (N=8; 17.1%). Bitruncular (N=7, 14.8%) and tritruncular (N=10; 21.2%) impairments were predominant. Thus, 165 arteries and/or bypasses were analyzed with significant stenoses being detected in 49 vessels (29.6%).

Out of 588 coronary segments analyzed, 67 (12.4%) were not visualized on the scanner or had a diameter lesser than 1.5 mm, leading to their being excluded from the analysis. Two significant stenoses, of which one was an occlusion of the second diagonal branch and one stenosis of the right posterior descending artery, were not diagnosed for these reasons. On the other hand, these two patients did present significant coronary lesions on different location which were included in the analysis (Fig. 1 and 2).

In total, 103 significant coronary stenoses were diagnosed (prevalence of 19.7%) out of 521 segments included in the analysis. Of these, 58 segments were considered evaluable on MDCT (11.1%), of which 14 (2.6%) were due to movement artifacts, 18 (3.4%) were due to metal structures (stents), and 26 (4.9%) were due to significant coronary calcification.

Table 1 illustrates the diagnostic accuracy of the test for the segments that could be evaluated. Table 2 shows the same data including the segments that could not be evaluated. Considering all of the segments analyzed, a strong correlation for the degree of stenosis determined by the two techniques was observed regardless of the type of analysis: Per segment (r = 0.80; P < 0.0001), per artery (r = 0.79; P < 0.001) or per patient (R = 0.81; P < 0.0001). The agreement or conformity between the MDCT and the conventional coronary angiography was good (κ=0.64) for per segment evaluation, and moderate for per artery and per patient analysis (κ = 0.57 and κ = 0.54 respectively). The 95% confidence interval for evaluating the degree of stenosis using 64-slice MDCT was −44 to 42% (Fig. 3). No inter-observer variation was calculated due to the agreement of the two readers with regard to difficult or uncertain cases on scanning. The intra-observer variability computed using the Cohen coefficient (κ) was 0.78.

The average estimated effective dose was 13 mSv.

Discussion

The clinical results of our work show very high diagnostic accuracy (96.3%) for evaluating segments using MDCT with adequate image quality. The specificity and negative predictive value of the technique are particularly high (97.1
Figure 2. Examples of non-invasive angiogram using 64-slice MDCT (right column) and corresponding images obtained using coronary angiography (left column). E. Venous aortocoronary bypass with two lesions in series (Arrow). F. The stenoses are visualized particularly well on MDCT (Arrows), as is the additional lesion at the origin of the bypass (Asterisk). G. Severe stenosis (Arrow) of the middle LAD in front of bifurcation with the second diagonal branch. H. This stenosis does not appear on the MDCT due to the presence of numerous calcifications (Arrow).

and 98.4% respectively), which confirms the results already reported in the international literature [2,4,10,11]. When we included segments in the analysis, which had poor image quality, the diagnostic accuracy, specificity and negative predictive value were still high (92.9, 97.4 and 94% respectively). The sensitivity dropped from 92.8 to 74.8%.

A percentage of 11.1% of segments could not be evaluated in our study, mainly due to the presence of severe coronary calcification. However, it is important to keep in mind that the previous work were conducted on a population different from the one in our study. Unlike in our study, exclusion criteria, such as the absence of known histories of coronary disease, aortocoronary bypass, stent implants, non-sinus rhythm and/or excessively high heart rate have widely been used. On the other hand, the use of beta-blockers was not systematic, which may explain the greater number of segments excluded from analysis by certain studies [10,12].

In our work, we evaluated a population of patients that were not selected so that we could assess the robustness of

<table>
<thead>
<tr>
<th>Degree of stenosis</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value %</th>
<th>Negative predictive value %</th>
<th>Diagnostic accuracy %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 50%</td>
<td>Segments</td>
<td>92.8% (84.9–97.3)</td>
<td>97.1% (94.9–98.5)</td>
<td>87.5</td>
<td>98.4</td>
</tr>
<tr>
<td></td>
<td>Arteries</td>
<td>72.9% (58.2–84.7)</td>
<td>96.6% (91.4–99.1)</td>
<td>89.7</td>
<td>89.6</td>
</tr>
<tr>
<td></td>
<td>Patients</td>
<td>75% (50.9–91.3)</td>
<td>88.9% (65.3–98.6)</td>
<td>88.2</td>
<td>76.2</td>
</tr>
<tr>
<td>&gt; 70%</td>
<td>Segments</td>
<td>92.2% (82.7–97.4)</td>
<td>97.2% (95.1–98.6)</td>
<td>84.3</td>
<td>98.7</td>
</tr>
<tr>
<td></td>
<td>Arteries</td>
<td>70.3% (53–84.1)</td>
<td>96.1% (91.1–98.7)</td>
<td>83.9</td>
<td>91.7</td>
</tr>
<tr>
<td></td>
<td>Patients</td>
<td>76.5% (50.1–93.2)</td>
<td>90.5% (69.6–98.8)</td>
<td>86.7</td>
<td>82.6</td>
</tr>
</tbody>
</table>

Detection of significant (> 50%) or severe (> 70%) coronary stenoses using 64-slice MDCT in a study population, excluding from the analysis segments that cannot be evaluated. The results are shown in analysis per segment, per artery and per patient.
Table 2  Diagnostic accuracy of the test for the segments that could not be evaluated.

<table>
<thead>
<tr>
<th>Degree of stenosis</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value %</th>
<th>Negative predictive value %</th>
<th>Diagnostic accuracy %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 50% Segments</td>
<td>74.8% (65.2–82.8)</td>
<td>97.4% (95.3–98.7)</td>
<td>87.5</td>
<td>94</td>
<td>92.9</td>
</tr>
<tr>
<td>Arteries</td>
<td>71.4% (56.7–83.4)</td>
<td>96.6% (91.4–99.1)</td>
<td>89.7</td>
<td>88.9</td>
<td>89.1</td>
</tr>
<tr>
<td>Patients</td>
<td>75% (50.9–91.3)</td>
<td>88.9% (65.3–98.6)</td>
<td>88.2</td>
<td>76.2</td>
<td>81.6</td>
</tr>
</tbody>
</table>

| > 70% Segments      | 77.6% (66.6–86.4) | 97.3% (95.3–98.6) | 83.1 | 96.2 | 94.4 |
| Arteries            | 70.3% (53–84.1) | 95.3% (90.1–98.3) | 81.3 | 91.7 | 89.7 |
| Patients            | 76.5% (50.1–93.2) | 90.5% (69.6–98.8) | 86.7 | 82.6 | 84.2 |

Detection of significant (> 50%) or severe (> 70%) coronary stenoses using 64-slice MDCT in a population study including all segments with a vessel diameter greater than 1.5 mm. The results are shown in analysis per segment, per artery and per patient.

The particularly low percentage of segments with severe movement artifacts (2.6%) represents a significant improvement by comparison with studies published previously with 16-slice scans [11–14].

In per patient analysis, the diagnostic accuracy of 64-slice MDCT dropped significantly as compared with per segment analysis (81.6% versus 92.9%). Similarly, although sensitivity and positive predictive value held at a similar level, specificity and negative predictive value dropped significantly during per patient analysis. The differences observed can be explained in part by the difference in the prevalence of disease depending on the type of analysis performed. In fact, the prevalence of disease has a strong influence on the positive and negative predictive values of a diagnostic test [15]. In per segment analysis, the prevalence of significant coronary lesions was 19.7%. This figure reaches 52.6% when patients are taken individually. The negative predictive value drops, therefore, in per patient analysis.

These data suggest that multislice scanning has limited clinical utility in the context of a non-selected population of patients who present symptoms or are at high risk of coronary disease.

Limitations

The number of patients included in this study is still modest and the evaluation is reduced to a single center (monocentric study). The non-selected population studied is, in fact, very heterogeneous. Solid conclusions can only be drawn in the sub-groups of patients who have stents or aortocoronary bypasses.

The irradiation dose inherent to non-invasive MDCT angiography is significant. It is estimated at nine to 14 mSv [16]. Thus, this radiation is not negligible in our study [17], but it must be compared with the mortality from invasive techniques, such as coronary angiography.

Conclusion

64-slice MDCT compared to conventional coronary angiography for detection of significant stenosis reveals good agreement after optimizing the acquisition protocol and image reconstruction. The diagnostic accuracy and negative predictive value during 64-slice MDCT are particularly high when coronary segments are evaluated individually. MDCT efficacy for determining the presence of significant coronary stenosis is, however, reduced when analyzing per patient, which limits considerably the use of multislice scanning on a non-selected population at high risk for coronary disease.

MDCT should be reserved for patients who are at low or intermediate risk for coronary disease and have sinus rhythm in order to meet the ideal conditions for obtaining best diagnostic performance. Improving tube’s rotation time, as well as spatial resolution should allow for further improve diagnostic performance, particularly when coronary stents or significant calcifications are present.

References

[1] Paul JF, Ohanessian A, Caussin C, et al. Visualization of coronary tree and detection of coronary artery stenosis using...


