CLINICAL RESEARCH

Accuracy of multislice computed tomography in the preoperative assessment of coronary disease in patients scheduled for heart valve surgery

Précision diagnostique du scanner 64 barrettes dans l’évaluation de la maladie coronaire avant la chirurgie valvulaire cardiaque

Réda Jakamy a,*, Olivier Barthélémy b, Claude Le Feuvre b, Emmanuel Berman b, Rhéda Boutekadja b, Philippe Cluzel b, Jean-Philippe Metzger b, Gérard Helft b

a Hôpital privé Saint-Martin, 18, rue des Roquemonts, 14000 Caen, France
b Heart Institute, Pitié-Salpêtrière University Hospital, Paris, France

Received 18 December 2011; received in revised form 3 May 2012; accepted 22 May 2012
Available online 17 July 2012

KEYWORDS
Coronary angiography; Coronary disease; Diagnostic accuracy; Multislice computed tomography; Valve surgery

Summary
Background. — Coronary angiography (CA), an invasive and expensive procedure, is still recommended in most patients referred for elective valve surgery. Multislice computed tomography (MSCT) is a promising alternative technique to rule out significant coronary artery lesions.

Aim. — To evaluate MSCT in detecting significant coronary artery lesions in patients referred for elective valve surgery.

Methods. — Between August 2007 and December 2010, patients referred for elective valve surgery were identified prospectively and underwent 64-slice MSCT and CA. We compared significant coronary stenoses, defined as a reduction of luminal diameter ≥ 50%, to establish the diagnostic accuracy of MSCT. All coronary segments were analysed and uninterpretable lesions were scored positive.

Results. — Forty-eight patients were included (62.5% male; mean age 65 ± 12 years), the majority had aortic insufficiency (37.7%) or aortic stenosis (32.0%). The prevalence of significant coronary artery stenoses was 27.1%. The sensitivity, specificity, positive and negative predictive values of MSCT were 77%, 89%, 71% and 91%, respectively, in a patient-based analysis; 82,

Abbreviations: AHA, American Heart Association; CA, coronary angiography; CABG, coronary artery bypass graft; CAD, coronary artery disease; CI, confidence interval; IQR, interquartile range; MR, mitral regurgitation; MSCT, multislice computed tomography.

* Corresponding author.
E-mail address: redjack@hotmail.fr (R. Jakamy).

1875-2136/$ — see front matter © 2012 Elsevier Masson SAS. All rights reserved.
http://dx.doi.org/10.1016/j.acvd.2012.05.004
Background

Various studies have shown that combined bypass and valve surgery of significant coronary artery disease (CAD) reduces early and late mortality [1]. Coronary angiography (CA) is the gold standard for diagnosing CAD, and is recommended in patients scheduled for valve surgery [2]. However, CA is an invasive and expensive procedure, with a small (0.1–0.2%) risk of major complications such as death, myocardial infarction and stroke. A primary non-invasive technique as an alternative to CA to improve preoperative risk stratification in patients referred for valve surgery is therefore highly desirable.

Multislice computed tomography (MSCT) has a good negative predictive value for ruling out CAD in patients with intermediate pre-test probability [3]. However, few studies have examined coronary artery assessment by MSCT in patients scheduled for elective valve surgery [4,5].

We conducted a prospective study to evaluate the diagnostic accuracy of 64-slice MSCT for the detection of significant artery lesions in patients referred for elective valve surgery.

Methods

Study population

Consecutive patients scheduled for valve surgery were screened prospectively from August 2007 to December 2010. As a previous study had shown good results for MSCT in patients with aortic stenosis [6], we initially excluded patients with aortic stenosis in order to explore the diagnostic accuracy of MSCT in patients with other valve diseases. However, owing to low patient numbers, from mid-2008 we also included patients with aortic stenosis. Exclusion criteria included: atrial fibrillation, previous coronary artery bypass graft (CABG), an unstable haemodynamic state, acute renal insufficiency, previous allergic reaction to iodine contrast media, pregnancy and lactation. The study was approved by the French Society of Cardiology; and all patients signed an informed consent form.

Patient preparation

MSCT and CA were performed in all patients within 3 weeks of each other. All patients with baseline heart rate greater
than 65 beats per minute received 5 to 10 mg of intravenous atenolol 10 min before the examination.

**MSCT protocol**

All scans were performed using a 64-slice MSCT (Philips, Brilliance 64 CT scanner, Eindhoven, Holland). The scan protocol included slices of the aortic artery for 10 patients for whom a trans catheter aortic valve implantation was discussed. Thus, the median radiation exposure for MSCT with this scan protocol was calculated as 16 mSv, although prospective X-ray tube modulation was used. A standardized examination protocol, with $64 \times 0.625$ mm collimation, pitch of 0.2 and a tube rotation time of 400 ms, was used. The typical tube voltage was 120 kV, with a tube current of 600–900 mA, depending on patient size, body mass index and thoracic diameters in the scan area. A mean of $114 \pm 23$ mL of iodine contrast agent (400 mgI/mL, Iomeron, Bracco, Milan, Italy) was injected continuously at a rate of 8 mL/s to explore solely the coronary arteries. A bolus tracking technique with automated detection of peak enhancement in the ascending aorta was used to time the scan. Coronary assessment was done during a single breath-hold.

Radiologists used multiplanar reformations and three-dimensional reconstructions to detect significant coronary stenoses, defined as a mean lumen reduction greater than 50%. They used the 17-segment American Heart Association (AHA) classification [7] to describe coronary lesions and they were blinded to clinical data. All vessels were included in the analysis, and any that were uninterpretable were scored as significant coronary stenoses.

**Coronary angiography**

Coronary angiograms were analysed by one experienced cardiologist [H.G.], who was unaware of the MSCT results, using a modified 17-segment AHA classification [7]. All coronary segments were visually assessed. Those with significant narrowing were quantified by a validated QCA algorithm (CAAS, Pie Medical, Maastricht, The Netherlands). They were evaluated in two orthogonal views, and were classified as significant if the mean lumen diameter reduction was greater than 50%.

**Statistical methods**

The diagnostic accuracy of MSCT was compared with that of CA as the reference standard for the detection of significant stenosis in the coronary arteries. All diagnostic accuracy parameters, sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios are given with their corresponding 95% confidence intervals (CIs). Interobserver agreement was assessed by Cohen Kappa statistics, and was performed for four analyses: by patient, by revascularization, by vessel and by segment.

Continuous variables are reported as medians and interquartile ranges (IQRs), and categorical variables as numbers and percentages. Comparisons between patients with and without aortic stenosis were performed using Student’s $t$ test for independent samples for continuous variables, and a $\chi^2$ test or Fisher’s exact test when appropriate for categorical variables. A $P$ value less than 0.05 was considered significant. All analyses used XLSTAT Version 2011.2.08 (Addinsoft Inc., New York, NY, USA).

**Results**

**Patient characteristics**

Of 66 consecutive patients scheduled for valve surgery during August 2007 to December 2010, 18 were excluded due to
limited patient and time availability to perform MSCT before surgery \((n = 11)\), withdrawal of written consent \((n = 5)\), acute renal insufficiency \((n = 1)\) and previous allergic reaction to iodine contrast media \((n = 1)\). Demographics of the remaining 48 patients are shown in Table 1. Most patients had aortic insufficiency \((37.7\%)\) or aortic stenosis \((32.1\%)\); five patients had a double valvular disease. Approximately half of the patients were overweight, had hypertension, were \((ex)\)-smokers, and had a left ventricular ejection fraction greater than 56\% (Table 1). The prevalence of CAD was 27.1\%, mainly one-vessel disease \((16.7\%)\) (Table 1).

**Patient-based analysis**

MSCT correctly excluded CAD in 31 patients, with a specificity of 89\% (Table 2). Four patients classified as having significant coronary lesions had the severity of stenoses overestimated. MSCT correctly identified significant coronary lesions in 10 of 13 patients, resulting in a sensitivity of 77\%. The diagnostic accuracy of a normal MSCT to detect patients without significant stenosis was 91\%. The agreement on the presence of significant coronary lesions between the MSCT and CA was good \((K\ value\ 0.64)\).

**Revascularization-based analysis**

Preoperative CA led to revascularization (CABG or percutaneous coronary intervention) in 11 of 48 patients \((22.9\%)\) (Table 2). Nine patients were correctly detected by MSCT, giving a sensitivity of 82\%. Among the five patients scored false positive, two were lost to follow-up. The specificity of 86\% would have prevented 32 CAs. The agreement between MSCT and CA to detect patients requiring coronary revascularization was good \((K\ value\ 0.62)\).

**Valve disease-based analysis**

Ten patients with severe aortic stenosis had significant coronary lesions \((59\%)\) (Table 2). Two of these patients were classified as false negatives, resulting in a sensitivity of 80\%. Specificity and negative predictive values were 86\% and 75\%, respectively. Agreement coefficient \(K\) was 0.64, suggesting a good correlation between MSCT and CA.

Among patients with severe aortic insufficiency, the negative and positive predictive values were 100\% and 33\%, respectively (Table 2). MSCT correctly identified no significant coronary lesions for the five patients with mitral stenosis, resulting in specificity and negative predictive values of 100\%. Only one of 11 patients with severe mitral regurgitation was classified as false negative. The sensitivity, specificity, positive and negative predictive values were 50\%, 89\%, 50\% and 89\%, respectively.

Table 3 shows the comparison of the baseline characteristics of patients with and without aortic stenosis. Patients with aortic stenosis were significantly older and significantly more likely to have CAD, hypertension and hypercholesterolaemia.

**Vessel-based analysis**

By MSCT, 163 of 192 vessels were correctly analysed as being free of lesions (Table 2). The sensitivity of 74\% is explained by the six false negatives. Three of the six lesions not detected by MSCT were in the circumflex artery. The severity of stenosis was overestimated in 11 arteries (one in the left main artery, four in the left anterior descending artery and six in the right coronary artery), which were classified as false positives. However, the specificity and negative predictive values were 94\% and 97\%, respectively. Cohen’s Kappa coefficient was 0.54, indicating a good agreement between the results of CA and MSCT to detect significant coronary lesions on a per-vessel analysis.

**Segment-based analysis**

No segments were excluded from the analysis, thus 720 segments were included for comparison with CA. Eight significant coronary stenoses in CA were underestimated by MSCT (Table 2), mainly in the distal epicardial trunks. The sensitivity and positive predictive values were 65\% and 52\% respectively. MSCT overestimated 14 coronary stenoses, considered false positives, including ten uninterpretable segments. The specificity and negative predictive values were 98\% and 99\% respectively.

The positive likelihood ratio of 32 indicates a significant change in post-test odds to detect significant coronary stenoses. The interobserver variability for the detection of significant stenoses in segments had a moderate value \(K\) of 0.56.

**Imaging**

Fig. 1 shows volume-rendered and multiplanar reconstructed MSCT images and the corresponding CA image from a patient who had a mitral regurgitation. The arrow shows a significant stenosis in the proximal left anterior descending artery, correctly identified by MSCT.

**Discussion**

In our study, MSCT was correct in 31 of 35 patients free of CAD and in ten of 13 patients with significant coronary lesions. The severity of the stenosis was underestimated in three patients and overestimated in four patients, therefore, CA could have been avoided in 31 of 48 patients \(64.5\%)\).

The 27.1\% prevalence of CAD in our study is high compared with that reported in previous studies \(20\% [6,8]\), and ensures the inclusion of patients with a high pre-test probability of CAD. MSCT allowed the detection of significant coronary stenoses, with a good sensitivity of 77\% and a high specificity of 88\%. The detection was correct in 41 of 48 patients \(85.4\%)\). Of the three patients classified as false negatives, two had severe aortic stenosis, resulting in a negative predictive value among patients with aortic stenosis that was lower \(75\%)\) than reported in previous studies \(100\% [6,8]\).

CAD is found in approximately one-third of patients with aortic stenosis \([9]\), but in our study, the prevalence of CAD was much higher \(59\%). The prevalence of a disease strongly influences the positive and negative predictive values of a diagnostic test \([10]\). Thus, the high prevalence tended to decrease the negative predictive value.
Table 2  Diagnostic performance of MSCT for the detection of stenoses greater than 50% on CA.

<table>
<thead>
<tr>
<th>Analysis by</th>
<th>Prevalence (%)</th>
<th>n</th>
<th>TP (n)</th>
<th>TN (n)</th>
<th>FP (n)</th>
<th>FN (n)</th>
<th>Kappa</th>
<th>Sensitivitya</th>
<th>Specificitya</th>
<th>PPVa</th>
<th>NPVa</th>
<th>+LRb</th>
<th>−LRb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient</td>
<td>27.1</td>
<td>48</td>
<td>10</td>
<td>31</td>
<td>4</td>
<td>3</td>
<td>0.64</td>
<td>77 (49—92)</td>
<td>89 (73—96)</td>
<td>91 (81—100)</td>
<td>6.7 (2.5—17.7)</td>
<td>0.2 (0.1—0.7)</td>
<td></td>
</tr>
<tr>
<td>Revascularizationc</td>
<td>22.9</td>
<td>48</td>
<td>9</td>
<td>32</td>
<td>5</td>
<td>2</td>
<td>0.62</td>
<td>82 (51—95)</td>
<td>86 (71—94)</td>
<td>94 (86—100)</td>
<td>6 (2.5—14)</td>
<td>0.2 (0—0.7)</td>
<td></td>
</tr>
<tr>
<td>Valvular heart disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>58.8</td>
<td>17</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>0.64</td>
<td>80 (47—95)</td>
<td>86 (46—100)</td>
<td>89 (68—100)</td>
<td>75 (45—100)</td>
<td>5.6 (0.9—35)</td>
<td>0.2 (0—0.8)</td>
</tr>
<tr>
<td>AL</td>
<td>5.0</td>
<td>20</td>
<td>1</td>
<td>17</td>
<td>2</td>
<td>0</td>
<td>0.46</td>
<td>100 (17—100)</td>
<td>89 (67—98)</td>
<td>33 (0—86)</td>
<td>100 (100—100)</td>
<td>9.5 (2.5—35)</td>
<td>0</td>
</tr>
<tr>
<td>MS</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100 (50—100)</td>
<td>—</td>
<td>—</td>
<td>100 (100—100)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MR</td>
<td>18.2</td>
<td>11</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>0.40</td>
<td>50 (10—90)</td>
<td>89 (54—100)</td>
<td>50 (0—100)</td>
<td>89 (60—100)</td>
<td>4.5 (0.4—45)</td>
<td>0.5 (0.1—2)</td>
</tr>
<tr>
<td>Coronary arteries</td>
<td>9.4</td>
<td>192</td>
<td>12</td>
<td>163</td>
<td>11</td>
<td>6</td>
<td>0.54</td>
<td>67 (41—86)</td>
<td>94 (89—96)</td>
<td>52 (31—72)</td>
<td>97 (92—98)</td>
<td>10.6 (5.4—20)</td>
<td>0.3 (0.2—0.7)</td>
</tr>
<tr>
<td>LM</td>
<td>0</td>
<td>48</td>
<td>0</td>
<td>47</td>
<td>1</td>
<td>0</td>
<td>—</td>
<td>—</td>
<td>98 (89—100)</td>
<td>—</td>
<td>100 (100—100)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>LAD</td>
<td>14.6</td>
<td>48</td>
<td>6</td>
<td>37</td>
<td>4</td>
<td>1</td>
<td>0.64</td>
<td>85 (46—99)</td>
<td>90 (76—96)</td>
<td>60 (30—90)</td>
<td>97 (92—100)</td>
<td>8.3 (3.3—23)</td>
<td>0.1 (0—0.9)</td>
</tr>
<tr>
<td>Cx</td>
<td>10.4</td>
<td>48</td>
<td>2</td>
<td>43</td>
<td>0</td>
<td>3</td>
<td>0.54</td>
<td>40 (12—76)</td>
<td>100 (92—100)</td>
<td>100 (100—100)</td>
<td>93 (86—100)</td>
<td>—</td>
<td>0.6 (0.3—1.2)</td>
</tr>
<tr>
<td>RCA</td>
<td>12.5</td>
<td>48</td>
<td>4</td>
<td>36</td>
<td>6</td>
<td>2</td>
<td>0.40</td>
<td>66 (30—90)</td>
<td>85 (71—93)</td>
<td>40 (9—70)</td>
<td>94 (87—100)</td>
<td>4.6 (1.8—12)</td>
<td>0.4 (0.1—1.2)</td>
</tr>
<tr>
<td>Segment</td>
<td>3.2</td>
<td>720</td>
<td>15</td>
<td>683</td>
<td>14</td>
<td>8</td>
<td>0.56</td>
<td>65 (44—81)</td>
<td>98 (96—99)</td>
<td>52 (33—70)</td>
<td>99 (98—99)</td>
<td>32 (17—59)</td>
<td>0.3 (0.2—0.6)</td>
</tr>
</tbody>
</table>

+LR: positive likelihood ratio; −LR: negative likelihood ratio; AI: aortic insufficiency; AS: aortic stenosis; Cx: circumflex; FN: false negative; FP: false positive; LAD: left anterior descending; LM: left main; MR: mitral regurgitation; MS: mitral stenosis; NPV: negative predictive value; PPV: positive predictive value; RCA: right coronary artery; TN: true negative; TP true positive.

a Data are % (95% confidence interval).
b Data are ratio (95% confidence interval).
c Revascularization by coronary artery bypass graft or percutaneous coronary intervention.
Coronary calcifications increase with age as well as the prevalence of CAD [11]. Their degree has a linear association with aortic valve calcifications [12]. Among patients with aortic stenosis, the lesions of the circumflex and right coronary arteries could not be correctly assessed because of calcifications. They were underestimated (false negatives), which explains the low negative predictive value (75%). Patients with aortic insufficiency were younger, with fewer valve calcifications, hence, an excellent negative predictive value of 100%.

As in previous studies, we chose to include all segments and score uninterpretable coronary lesions on MSCT as significant coronary stenoses, at the risk of obtaining low specificity and positive predictive values [13]. However, the specificity of 98% and negative predictive value of 99% were very high, proving the excellent diagnostic accuracy of MSCT to detect vessels without significant stenosis. The high diagnostic accuracy of MSCT is mainly due to its negative predictive value for the exclusion of CAD [14]. Our results confirm the high diagnostic accuracy for excluding coronary artery disease in patients with a scheduled heart valve surgery.

The analysis by revascularization provides data that are more realistic in terms of usual clinical practice. With two patients lost to follow-up, 11 coronary patients (22.9%) underwent revascularization with CAGB or coronary angioplasty, but the negative predictive value of MSCT remained high. Over half of significant coronary stenoses do not have a haemodynamic impact [16], and the revascularization of non-ischaemic coronary lesions does not have a beneficial impact on morbidity and mortality [17]. Even when detecting significant coronary stenoses, MSCT cannot be used to judge the benefit of revascularization. It is disappointing that the data according to revascularization were not included in previous studies [4,6]. Having information from a larger number of patients would be more informative than simply a comparison with the results of CA, since we have to deal with both patients lost to follow-up and with distal significant coronary stenosis requiring medical treatment without a revascularization procedure.

Radiation exposure with MSCT is higher than with CA [19]. Despite the use of prospective X-ray tube modulation, which can reduce radiation exposure by 50%, our mean effective dose was very high (20 ± 10 mSv). The main reason for this is that our acquisition protocol was not focused solely on the coronary arteries, but also associated aortic artery slices in 10 of 48 patients (20.8%) with aortic stenosis, for whom a transcatheter aortic valve implantation was discussed. Respecting the acquisition protocol, one can obtain lower effective doses (mean 8.6±2.8 mSv for a 64-slice MSCT [20]).

**Study limitations**

One limitation to our study is the exclusion of patients with atrial fibrillation, haemodynamic instability, previous revascularization by CAGB and kidney failure. Atrial fibrillation has long been considered a hindrance to the quality of
MSCT images. However, recent studies have demonstrated a lack of consequence of an irregular rhythm on image interpretation with MSCT [4,8]. Therefore, atrial fibrillation is no longer a concern with MSCT using electrocardiographic gating for image reconstruction to obtain nearly motion-free image quality. Too many exclusion criteria tend to decrease the number of false positives and wrongly favour the specificity and positive predictive value of the study [15]. Selection biases may limit the generalization of MSCT.

Previous studies have shown great interest in finding the most accurate Agatston score threshold for recommending MSCT as a first-line means of ruling out CAD [5,18]. However, we did not collect data for the quantification of coronary calcium score.

**Conclusions**

In these patients referred for elective valve surgery, MSCT had a high diagnostic accuracy to rule out significant coronary stenoses. However, larger multicentre studies in an unselected population of patients are needed to determine its place within the range of diagnostic tools for the preoperative assessment of valvular heart disease.

**Disclosure of interest**

This study was funded by a grant from the Société Française de Cardiologie. The funding sponsor had no role in study design; in the collection, analysis, and interpretation of data, or in the writing of this report.

**Acknowledgements**

This study was conducted through a team research scholarship by the French Federation of Cardiology. We wish to thank Emilie Nannonette, Clinical Research Manager from the Société Française de Cardiologie, for her essential support in the conduct of this study.

**References**


MSCT for assessing coronary disease before heart valve surgery


