Value of multislice CT coronary arteries calcification scoring in the prediction of coronary arteries pathology in chronic kidney disease patients

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Abstract Purpose: To determine the value of multislice CT coronary artery calcification (CAC) scoring in the prediction of future cardiac events in known chronic kidney disease (CKD) patients using conventional coronary angiography as the standard reference.

Patients and methods: Fifty-eight patients with CKD on hemodialysis underwent CT CAC scoring using multislice scanner and conventional coronary angiography. Results of CAC scoring were compared to the findings of conventional coronary angiography.

Results: Mean CAC scoring in patients with significant coronary arteries stenotic lesions was higher than in patients with no significant coronary arteries stenotic lesions with significant difference ($P < 0.001$).

Mean patient CAC scoring was strongly correlated with the number of coronary arteries with significant stenotic lesions ($r = 0.910$).

Abbreviations: CAC, coronary artery calcification; CKD, chronic kidney disease; CVD, cardiovascular disease.

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Conclusion: CT CAC scoring is a non-invasive technique which can be used in the evaluation and follow up of CKD patients’ coronary arteries without the use of contrast medium reducing the number of invasive coronary angiography needed.

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1. Introduction

In the general population, the presence and extent of coronary artery calcification (CAC) have been used for the non-invasive diagnosis of coronary artery disease in both symptomatic and asymptomatic patients. Vascular calcification is a common complication of chronic kidney disease (CKD). In new hemodialysis patients the prevalence of CAC is 64% and in the established hemodialysis patients CAC prevalence is up to 92% (1,2).

Chronic kidney disease patients are susceptible to ischemic heart disease more frequent than ordinary people and approximately 50% of these patients die from cardiovascular disease (3,4). The risk of death increases 500–1000 folds in hemodialysis patients and even after transplantation, the risk of death is >5 folds more than age matched general population (5).

Electron beam computed tomography (EBCT) and more recently multislice computed tomography (MSCT) have been used for the detection of CAC and its quantification. MSCT is more widely available than EBCT (6–8).

Aim of this work was to determine the value of multislice CT coronary artery calcification (CAC) scoring in the prediction of future cardiac events in known CKD patients using conventional coronary angiography as the standard reference.

2. Patients and methods

2.1. Study population

During the period between April 2009 and January 2010, 58 patients with stage 5 CKD (chronic kidney disease with glomular filtration rate <15 ml/min) on regular hemodialysis were referred for conventional coronary angiography as a pretransplant evaluation.

All patients were prospectively evaluated with non-enhanced CT CAC scoring using MSCT scanner (conducted and evaluated by the radiologist) followed by conventional coronary angiography (conducted and evaluated by the cardiologists). Conventional coronary angiography was done within 2 months period from the CT CAC scoring. Study was approved by the hospital ethics committee and a written informed consent was obtained from all patients.

Exclusion criteria included (1) unstable symptoms, electrocardiographic (ECG) or vital sign changes, (2) previous bypass surgery or coronary artery stent placement, (3) pregnancy, (4) patients with irregular cardiac rhythm.

Patients were divided into four groups: first group with no significant coronary arteries stenotic lesions (N = 21); second group with single coronary artery with significant stenotic lesions (N = 3); third group with two coronary arteries with significant stenotic lesions (N = 12); and fourth group with more than two coronary arteries with significant stenotic lesions (N = 22).

2.2. CT imaging and interpretation

All CT scans were obtained using a 64 slice multi-detector row CT scanner (Lightspeed VCT; GE Healthcare, Milwaukee, WI, USA). Non-enhanced ECG gated cardiac CT was performed with the following parameter: scan type = cine, rotation time = 0.35 s, rotation length = segment (not full rotation), detector coverage = 40 mm, cine time between images = 0.05 s, axial slice thickness = 2.5 mm, images/rotation = 16 image, cine duration = 0.3 s.

Images were acquired in the cranio-caudal direction from 3 cm above the aortic arch to the costophrenic angle in one breath hold. Patients who were unable to hold their breath were asked to breathe as shallow as possible during acquisition. The system was synchronized with the cardiac cycle (ECG gated) to trigger scanning during the diastolic phase.

Images were reconstructed from data acquisition window centered at 70% of the R–R interval at ECG gating. Post-processing was done using workstation (Advantage Workstation 4.3.; GE Healthcare, Milwaukee, WI, USA). Images were reviewed in standard mediastinal window. Calcium score was determined on the external workstation using calcium scoring software (version 3.5, Smartscore). According to the Agatston method, we define the regions of interest by vessel and slice with the threshold option is set to pixels with an intensity ≥130 Hounsfield units were counted and data were analyzed using the software.

CT calcium score in each coronary artery was termed CT CAC score. Patient CT CAC score was calculated as the sum of the individual coronary arteries CT CAC score.

2.3. Conventional coronary angiography

Conventional coronary angiography (the reference standard) was performed according to the standard techniques using a flat-panel fully digital system (Innova 2000, General Electric Medical Systems, Milwaukee, USA).

2.4. Image analysis

For analysis of the coronary arteries we considered each of the following as separate artery: left main, left anterior descending, left circumflex, first diagonal, second diagonal, first obtuse marginal, second obtuse marginal, right coronary, posterior descending branch, and postero-lateral branch.

All arteries with diameter larger than 2 mm in the conventional coronary angiography were included in the analyses of conventional angiography and CT CAC score. Coronary artery with stenotic lesions was diagnosed when at least one stenotic lesion noted with lumen reduction greater than or equal to 50%.
2.5. Statistical analysis

Descriptive statistics were calculated for patient age, sex and mean CT CAC score. Statistical analysis was performed using Minitab software version 12.2 for windows. Results were expressed as mean ± standard deviation. T test, Mann–Whitney test and Pearson’s correlation coefficient with confidence interval of 95% for coefficients were used each when applicable. P values less than 0.05 were accepted as statistically significant.

3. Results

This study included 58 patients with mean age 53.6 ± 10.3 years (range 30–68 years). There were 37 males and 21 females. All patients did coronary angiography within 2 months after the CT CAC score.

Mean duration of CKD was 2.9 ± 2.1 years. Duration of CKD was highly correlated to the patient CT CAC score (r = 0.788).

All patients showed coronary artery calcifications. Weak correlation was found between patient CT CAC score and patient age (r = −0.650) (Fig. 1) and also between patient age and number of coronary arteries with significant stenotic lesions (r = 0.024). No significant difference was found between age of patients with no significant coronary arteries stenotic lesions and patients with coronary arteries with significant stenotic lesions (P = 0.857).

Mean CT CAC score of all the patients was 746 ± 671 (range 35–2279). Mean CT CAC score of patients with coronary arteries with significant stenotic lesions was higher than the mean CT CAC score of patients with coronary arteries with no significant stenotic lesions (Table 1). Significant difference was found between the mean CT CAC score of patients with coronary arteries with no significant stenotic lesions and patients with coronary arteries significant stenotic lesions (P < 0.001) (Fig. 2).

All patients with coronary arteries with no significant stenotic lesions showed CT CAC score below 102 except one patient shows CT CAC score = 256 and all patients with more than two coronary arteries with significant stenotic lesions showed CT CAC score above 1000 except one patient showed CT CAC score = 973. All patients with two coronary arteries with significant stenotic lesions showed CT CAC score between 297 and 953, while all patients with single coronary artery with significant stenotic lesions were above 150 (Table 2).

Mean patient CT CAC score increased with the increased number of coronary arteries with significant stenotic lesions from 81 ± 44 in the first group to 1499 ± 325 in the fourth group (P < 0.001). Strong correlation was found between CT CAC score and number of coronary arteries with significant stenotic lesions (r = 0.910).

Coronary arteries with no significant stenotic lesions were 485 with mean CT CAC score = 45 ± 164 and number of coronary arteries with significant stenotic lesions were 95 (Table 3) with mean CT CAC score = 238 ± 398. Significant difference (P < 0.001) was found between CT CAC score of coronary arteries with no significant stenotic lesions and coronary arteries with significant stenotic lesions.

Left anterior descending artery (LAD) (Fig. 4) was the commonest involved artery (mean CT CAC score = 532 ± 519) followed left circumflex artery (LCX) (Fig. 5) (mean CT CAC score = 119 ± 145) and the same was found in the conventional coronary angiography as LAD involved in 27 patients followed by LCX in 23 patients.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>CT coronary artery calcification score in patients with no significant stenotic lesions and patients with significant stenotic lesions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>Number</td>
</tr>
<tr>
<td>All</td>
<td>58</td>
</tr>
<tr>
<td>No significant stenotic lesions</td>
<td>21</td>
</tr>
<tr>
<td>With significant stenotic lesions</td>
<td>37</td>
</tr>
</tbody>
</table>

SD = standard deviation.
4. Discussion

Hemodialysis patients experience an extraordinary high rate of cardiovascular mortality (9). CAC in CKD patients are more likely to occur more than in ordinary people. Moreover, it has been reported that the severe calcification seen in patients with CKD, actually begins long time before renal insufficiency requires dialysis (3,10).

Conventional coronary angiography is the golden standard modality for coronary artery evaluation yet, the associated high cost, usage of contrast medium, and significant procedure related mortality and morbidity rates have motivated the search for a non-invasive alternative modality to assess the coronary arteries (7). The recent advances in MSCT have led investigators to study more widely the MSCT CT CAC score (7).

This study was conducted to evaluate the value of multislice CT CAC score in proven CKD patients. CT CAC score was higher in the coronary arteries with significant stenotic lesions than in coronary arteries with no significant stenotic lesions and the mean patient CT CAC score was correlated to the number of coronary arteries with significant stenotic lesions noted in the conventional coronary angiography.

All patients showed CAC and this was in agreement with Braun et al. (11) who noted that CAC was much more common in CKD patients than in normal patients and similar findings were noted by Oh et al. (12).

Weak correlation was found between patient CT CAC score and age and also weak correlation was found between age and number of coronary arteries with significant stenotic lesions, and this was in agreement with Wayhs et al. (13).

Mean CT CAC score of patients with coronary arteries with significant stenotic lesions was higher than the mean CT CAC score of patients with coronary arteries with no significant stenotic lesions with significant difference and this was in agreement with Wayhs et al. (13) who found that mean patient CT CAC score was significantly greater in patients with hard coronary events than in patients with no coronary events. Similar findings were noted by Oh et al. (12), Lau et al. (14) and Haberl et al. (15).

Mean patient CT CAC score increased with the increased number of coronary arteries with significant stenotic lesions from coronary artery with no significant stenotic lesions group to the fourth group (more than two coronary arteries with significant stenotic lesions) with significant different between all groups. Also strong correlation was found between CT CAC score and the number of coronary arteries with significant stenotic lesions and this was in agreement with Haydar et al. (16) who found that CAC directly correlated with the number of coronary arteries with significant stenotic lesions.

All patients with CT CAC score above 972 had more than two coronary arteries with significant stenotic lesions and this was in agreement to Wayhs et al. (13) who found that CT CAC score $\geq 1000$ had a very high risk for coronary events.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>CT coronary artery calcification score of the different groups of coronary arteries.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Number</td>
</tr>
<tr>
<td>No stenotic lesions</td>
<td>21</td>
</tr>
<tr>
<td>Single artery with stenotic lesions</td>
<td>3</td>
</tr>
<tr>
<td>Two arteries with stenotic lesions</td>
<td>12</td>
</tr>
<tr>
<td>More than two arteries with stenotic lesions</td>
<td>22</td>
</tr>
</tbody>
</table>

SD = standard deviation.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>CT coronary artery calcification score in coronary arteries with no significant stenosis and coronary arteries with significant stenosis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>Number</td>
</tr>
<tr>
<td>All</td>
<td>580</td>
</tr>
<tr>
<td>With no significant stenosis</td>
<td>485</td>
</tr>
<tr>
<td>With significant stenosis</td>
<td>95</td>
</tr>
</tbody>
</table>

SD = standard deviation.

Figure 3 Dotplot diagram of the mean CT CAC score of the different coronary artery groups. Significant differences were found between mean patient CT CAC score of the different groups.
Haberl et al. (15) found CT CAC score $\geq 100$ highly suggestive of coronary arteries stenoses with high sensitivity and specificity and similarly in this study all patients with coronary arteries with significant stenotic lesions had CT CAC score above 150. These findings were in contrast to Lau et al. (14) who advise a level of 400 and the reason of the discrepancy may be because they used an older version of MSCT (four detector row MSCT) and in the current study we used 64 detector row MSCT. Patient CT CAC score showed weak correlation to age and strong correlation to the number of coronary arteries with significant stenotic lesions. CT CAC score above 300 was associ-

**Figure 4** Conventional coronary angiography A and axial CT B and C. Stenotic lesions is noted in the proximal third LAD (arrow) and proximal half of the LCX (arrow head) with calcification in both arteries in the axial CT.

**Figure 5** Conventional coronary angiography A and axial CT B. Stenotic lesion is noted in the distal half of the LCX (arrow head) with calcification in axial CT. Axial CT showed also tiny calcification in the LAD.
ated with coronary artery significant stenosis and above 1000 was associated with multiple coronary arteries with significant stenotic lesions.

5. Conclusion

CT CAC scoring is a non-invasive technique which can be used in the evaluation and follow up of CKD patients’ coronary arteries without the use of contrast medium reducing the number of invasive coronary angiography needed.

References