The diagnostic performance of Agatston score versus a novel lesion specific coronary artery calcium score in 100 kV and 120 kV scans

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Purpose

In search for effective preventive measures for coronary artery disease (CAD), a lot of effort has been put into finding an optimal screening tool. In 1990 Agatston described a method of quantifying the amount of coronary artery calcium. Using native, ECG gated CT images, the calcified plaques in coronaries can be visualized. Agatston Coronary Artery Calcium Scoring (A-CACS) has been the most commonly used scoring method of coronary calcium since its introduction. [1-2]

In practice

Since presence of calcium in arteries reflects advanced stages of coronary artery disease, it seems obvious to use calcium scoring as a marker of atherosclerosis. [3] In numerous large prospective studies A-CACS has shown to be a strong independent predictor of adverse cardiac events in asymptomatic individuals. Therefore it's most common use is cardiovascular risk stratification. Other studies have shown that CACS can indicate the presence of coronary stenosis. We sought to assess the latter use in our study. [4-5]

Lower dose scanning

Although the amount of radiation that is used for a calcium scoring scan is low, efforts have been made to lower the radiation exposure even more. [6-7] Lowering voltage, lowers the radiation dose. To measure the effect of lowering voltage on diagnostic performance in calcium scoring we scanned a part of our group at 100 kV. Marwan et al. showed it is possible to use this lower voltage, although it leads to an overestimation of the amount of calcium. [8-9]

Gold standard

Coronary CT Angiography (CCTA) has proven to be a good method of assessing the presence of coronary artery disease. High diagnostic values have been found in different studies. [10-11]

A new scoring method

A-CACS is a score based on the amount of calcium found in the whole heart. It does not take the distribution over the different plaques into account. A single plaque with high calcium load can still lead to a low A-CACS. Lesion-Specific Coronary Artery Calcium Scoring 3D (LS-CACS 3D) has been described by Qian et al. to be a better predictor
of presence of obstructive CAD. In our study we compare diagnostic performance of a novel LS-CACS 3D with conventional A-CACS. [12-13]

As a secondary goal we investigated influence of tube voltage on diagnostic performance of both scoring methods. In our study we scanned patients with 100 kV and 120 kV.
Methods and Materials

Patients:

This was a retrospective, single centre, comparative study in patients who were having an elective Coronary CT angiography (CCTA) at the Heart Center of the Semmelweis University in Budapest in the period from August until December 2012. Since comparing calcium scores is not meaningful in patients without calcium, we excluded patients with a calcium score under 10.

Exclusion criteria were:

- Presence of mechanical prosthetic valves
- Implantable cardioverter defibrillators
- Bad CCTA quality inhibiting diagnosis due to for example movement or breathing artefacts
- Bad native scan quality

CT Imaging Protocol:

Scans were performed with a 256-slice CT-scanner at 100 and 120 kilovolt using prospective ECG triggering, also known as "Step-and-shoot" mode. Scanner parameters were automatically adjusted to achieve diagnostic image quality. First we acquired a native or non contrast enhanced scan and then the contrast enhanced scan. The scan time was done in one single breath hold and performed in the craniocaudal direction. All images were reconstructed using iterative reconstruction. In our study we used CTDI to measure the dose used for the study. [14]

Coronary Calcium Scoring

For the Coronary artery Calcium Scoring we used in-house software developed by Szilard Voros' research group for assessing LS-CACS Fig. 1 on page 7. [12-13] We loaded DICOM files containing native images from the CCTA into the program. The program highlighted all areas with pixels exceeding a predefined threshold of 130 Hounsfield Units (HU), corresponding to calcium on a non contrast scan. Since we used 100 kV in a subgroup of our population, we used a threshold of 147 HU for that group instead. [9] Of every scan the researcher quantified image quality with the program by determining signal to noise ratio in the centre of the aorta. He then annotated the ostia of left main coronary artery (LMCA), left anterior descending artery (LAD) and left circumflex artery (LCx), and right coronary artery (RCA). The researcher then manually selected the highlighted intracoronary lesions and marked them with the corresponding coronary artery. The program then automatically propagated into the z-direction when the lesion covered multiple images. If a lesion covered more than two vessels it was labelled as it was located in the vessel with the largest portion. The program calculates the Agatston
score for each lesion. The maximal score for a lesion in a heart is the LS-CACS. The A-CACS is a summation of scores of all lesions. The novel LS-CACS 3D is calculated in a similar way as the LS-CACS. The difference is that to calculate the Agatston score the whole 3D volume of a lesion and the highest value the whole 3D lesion is used.

Gold standard

As a gold standard in this study we used CCTA. The images were analyzed for CAD by experienced physicians on a 3-dimensional workstation using software of the CT-scanner manufacturer. As described by SCCT guideline we divided the coronary artery tree into the same four categories as we did with the calcium scoring. We assessed each territory for obstructive CAD defined by a stenosis of ≥ 70% luminal narrowing.[15]

Statistics

Statistical analysis was done with IBM SPSS Statistics version 20.0.0. Normality of variables was determined with the Shapiro-Wilk test. [16] When normally distributed we compared continuous variables with the unpaired 2-tailed t-test. [17] Two continuous variables that were not normally distributed were compared with the Mann-Whitney test.
Fig. 1: Screenshot of Lesion-Specific Calcium Scoring Software

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Results

Patient Population

We examined 310 patients. 177 (57 %) were male and mean age (SD) was 56 ± 12 years. Most patients received a coronary CT angiography due to atypical angina. Among other reasons for the investigation were newly diagnosed heart failure and preoperative risk assessment. Severe stenosis was present in 42 patients (14%). 3 patients (1 %) with a calcium score of 0 had a significant stenosis. 146 (47 %) patients had detectable calcium (CAC > 10). The patient characteristics for these patients are listed in Table 1 on page 9 .

7 patients were excluded. 5 had severe movement artifacts, 1 had a giant coronary aneurysm and 1 native scan did not cover the whole coronary system.

Influence of voltage

The medians [IQR] of A-CACS were 113 [39-325] at 120 kV and 163 [53-336] at 100 kV (p = 0.33). For LS-CACS 3D we found 62 [31-101] for 120kV and 72 [36-166], which were not significantly different (p = 0.24). When we compared the A-CACS and LS-CACS of 120 kV scans between stenosed and non-stenosed patients we found different scores (for both: p < 0.001) Similar results were found when we did the same comparison at 100 kV (A-CACS: p < 0.003; LS-CACS: p < 0.009) Fig. 2 on page 9 . Image noise was not different for both scanning methods: for 100 kV median image noise was 20 [16-25] and for 120 kV 20 [16-23] (p<0.001). For all 120 kV scans tube current time product was 30 mAs, where for all 100 kV scans this was 50 mAs. CTDI values were similar for all scans.

Comparing A-CACS and LS-CACS 3D

We compared the two calcium scoring methods by plotting ROC curves at different voltages Fig. 3 on page 10 Fig. 4 on page 11 . The AUC's at 100 kV were 0.71 for A-CACS and 0.69 for LS-CACS 3D. AUC were higher when we did calcium scoring on 120 kV scans. We found an AUC of 0.81 for A-CACS and 0.83 for LS-CACS.
Fig. 2: Comparison of A-CACS an LS-CACS at different voltages between patients with and without stenosis.

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<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value n (%)</th>
<th>Median [IQR]</th>
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<tbody>
<tr>
<td>Age</td>
<td>62 ± 10</td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>92 (63)</td>
<td></td>
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<tr>
<td><strong>CAC Scoring method</strong></td>
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<tr>
<td>Whole Heart Agatston</td>
<td>125 [51, 323]</td>
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<tr>
<td>Lesion Specific Volume</td>
<td>62 [31, 150]</td>
<td></td>
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<tr>
<td><strong>Indication of examination</strong></td>
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<td></td>
</tr>
<tr>
<td>Atypical angina</td>
<td>91 (62)</td>
<td></td>
</tr>
<tr>
<td>Typical angina</td>
<td>39 (27)</td>
<td></td>
</tr>
<tr>
<td>Atrial evaluation for atrial fibrillation</td>
<td>12 (8)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4 (3)</td>
<td></td>
</tr>
<tr>
<td>Stenosis ≥ 70% present</td>
<td>39 (27)</td>
<td></td>
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<tr>
<td><strong>Voltage</strong></td>
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<td></td>
</tr>
<tr>
<td>100 kV</td>
<td>64 (44)</td>
<td></td>
</tr>
<tr>
<td>120 kV</td>
<td>83 (56)</td>
<td></td>
</tr>
<tr>
<td>Tube current-time product in mA * s</td>
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<tr>
<td>CT Dose Index</td>
<td>2.4 [2.4, 2.5]</td>
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</tr>
<tr>
<td>Number of CT-slices</td>
<td>63 [62, 64]</td>
<td></td>
</tr>
<tr>
<td>Image noise</td>
<td>20 [16, 24]</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1:** Characteristics of patients with a CACS > 0

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Fig. 3: ROC curves A-CACS and LS-CACS at 100 kV

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Fig. 4: ROC curves A-CACS and LS-CACS at 120 kV

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Conclusion

Scanning with 100 kV is good way to reduce the amount of radiation that is used to perform a calcium scoring scan. However the results from the ROC curves show that calcium scoring on 120 kilovolt scans is superior to the 100 kilovolt in predicting obstructive CAD. Although there is also a significant difference in scores between patients with stenosis and no stenosis, more overlap of calcium scores can be seen on the box-plot of 100 kV scans.

In our study the CT-scanner automatically adjusted the tube current time product to achieve a desired level of image quality. CTDI$_{vol}$ was kept at the same level in all scans as a result. Therefore the amount of radiation we used was not found to be lower and the image noise was the same. So our project can be seen as a comparison of the conventional 120 kV calcium scoring with an optimal 100 kV calcium scoring. A possible future project could be done without adjusting other scanner parameters and in that way lower CTDI$_{vol}$. It would be interesting to see if scanning with lower dose and an increase of image noise would actually lead to a significant decrease in diagnostic performance. Since increasingly lower radiation doses are used for CCTA, lowering radiation dose in calcium scoring is becoming increasingly important for its use in the future. [6-7]

Since calcium scoring on 120 kV scans had a better diagnostic performance, we focused our research on that specific group. We found LS-CACS 3D to have a higher AUC at that voltage and therefore a higher diagnostic performance in identifying patients with obstructive CAD.

We conclude that the LS-CACS 3D can be a useful method to assist physicians in diagnosing patients with obstructive coronary artery disease.
References


