The heart of patients with aortic aneurysms: evidence from cardiac computed tomography

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1. Introduction

Patients with abdominal aortic aneurysms (AAA) are known to have a high prevalence of coronary artery disease (CAD). Complications involving the heart represent the major cause of peri-procedural death accounting for about 7% mortality [1]. Thus, investigation and treatment for CAD is important in order to improve the long-term outcome of patients intended to undergo AAA repair [2].

Various scores have been developed for stratifying the cardiovascular risk. The Framingham method is a multivariable statistical model and can be used as a surrogate for cardiovascular morbidity and mortality [3]. Despite of the clinical use of such scores, however, limitations exist that may result in a failure to discriminate patients who will or will not experience peri-procedural or long-term cardiac complications [4].

Cardiac computed tomography (CT) allows for measuring the coronary calcium burden and for evaluating the coronary arteries with respect to stenoses calcium scoring has been shown to be an accurate method for the prediction of future cardiac events [4, 5], whereas CT coronary angiography allows to reliably diagnose significant coronary stenoses [6]. In addition, CT data can be used to accurately assess left ventricular (LV) function [7].

The purpose of this study was to determine the distribution of coronary calcium, the prevalence of coronary stenoses, and the global LV systolic function using cardiac CT in relation to traditional cardiovascular risk factors in patients prior to AAA repair.

2. Materials and methods

2.1. Patients

From July 2007 to January 2008, 60 consecutive patients (six females; 72.2 ± 9.0 years) underwent cardiac CT prior to elective AAA repair (Table 1). All patients underwent CT calcium scoring and coronary angiography [contraindications: renal insufficiency (n = 2), hypersensitivity to contrast medium (n = 0)].

Time interval between CT and AAA repair was 15 ± 18 days (1–65 days). Our local Ethics Board approved this single center study and waived the informed consent.
Table 1
Patient demographics and characteristics (n=60)

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>90%</td>
</tr>
<tr>
<td>Females</td>
<td>10%</td>
</tr>
<tr>
<td>Age (years)</td>
<td>72.2 ± 9.0</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>26.4 ± 4.0</td>
</tr>
<tr>
<td>Cardiac risk factors</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>87%</td>
</tr>
<tr>
<td>Nicotine abuse</td>
<td>70%</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>52%</td>
</tr>
<tr>
<td>Family history</td>
<td>13%</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>8%</td>
</tr>
<tr>
<td>Cardiovascular risk</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>33%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>27%</td>
</tr>
<tr>
<td>High</td>
<td>40%</td>
</tr>
<tr>
<td>Cardiac symptoms</td>
<td></td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>90%</td>
</tr>
<tr>
<td>Typical chest pain</td>
<td>7%</td>
</tr>
<tr>
<td>Atypical chest pain</td>
<td>3%</td>
</tr>
<tr>
<td>History of myocardial infarction</td>
<td>12%</td>
</tr>
<tr>
<td>Previous CABG or PCI</td>
<td>13%</td>
</tr>
<tr>
<td>Vascular co-morbidities</td>
<td></td>
</tr>
<tr>
<td>Peripheral arterial occlusive disease</td>
<td>23%</td>
</tr>
<tr>
<td>Cerebrovascular occlusive disease</td>
<td>8%</td>
</tr>
<tr>
<td>Renal artery occlusive disease</td>
<td>5%</td>
</tr>
</tbody>
</table>

Data are percentages or mean ± standard deviation. CABG, coronary bypass graft; PCI, percutaneous coronary intervention.

2.2. Cardiovascular history and Framingham risk scoring (FRS)

One observer reviewed the patient medical records with regard to the cardiovascular history. Cardiovascular risk factors were assessed on the basis of the FRS [3].

2.3. Cardiac CT data acquisition and image reconstruction

All patients underwent dual-source CT (Somatom Definition, Siemens Healthcare, Forchheim, Germany) calcium scoring and coronary angiography. After the non-enhanced scan for calcium scoring, 80 ml of contrast material (Ultra-vid 370, Bayer Schering Pharma) were administered at a flow rate of 5 ml/s, followed by 30 ml of saline solution. Start of data acquisition was controlled by bolus-tracking (threshold 140 HU).

Slice acquisition was performed by 2 × 64 × 0.6 mm, the pitch was 0.2–0.5, tube potential was 120 kV. The tube current time product was set at 80 mAs/rotation for the non-enhanced scan, and at 330 mAs/rotation for the contrast-enhanced scan. Non-enhanced CT-scans were reconstructed at 70% of the RR-interval using 3.0 mm non-overlapping slices (kernel B35f). CT coronary angiography data were reconstructed in 5% steps throughout the cardiac cycle with a slice thickness of 0.75 mm (increment 0.5 mm) (kernels B26f and B46f).

2.4. Calcium scoring

One experienced reader determined the Agatston score (AS) [8] using dedicated software (Syno CaScore, Siemens Healthcare).

Based on the AS, patients were subdivided: patients with an AS = 0; 0 < AS ≤ 100; 100 < AS ≤ 400; 400 < AS ≤ 1000; AS > 1000.

The AS-related risk of each patient was stratified using age- and gender-related percentiles [9]: patients with an AS ≤ 25th percentile; 25th < AS ≤ 50th percentile; 50th < AS ≤ 75th percentile; 75th < AS ≤ 90th percentile; AS > 90th percentile.

Patients with an AS > 75th percentile were classified to be at high risk [9].

2.5. CT coronary angiography

CT data were assessed by two independent observers. Coronary segments were classified as being of diagnostic or non-diagnostic image quality. Both readers assessed all diagnostic segments for the presence of significant coronary artery stenoses (diameter reduction > 50%) on multi-planar reformations. For any disagreement in data analysis, consensus agreement was appended.

2.6. LV function

LV function was determined using semi-automated software (Syno Circulation, Siemens Healthcare). End-systolic and end-diastolic phases were visually identified. Epicardial and endocardial contours were semi-automatically detected and corrected, if necessary. From calculated volume data, the ejection fraction (EF) was calculated and considered normal when > 50%.

2.7. Statistical analysis

All statistical analyses were performed by using commercially available software (SPSS, release 15.0, Chicago, IL, USA). Inter-observer agreements concerning image quality and the presence or absence of significant coronary artery stenosis were assessed by using kappa (κ) statistics. Correlation analyses were performed using Spearman rank order correlation coefficients. Correlations were assessed between the dimensions of AAA, AS, AS-related percentiles, FRS, and extent of CAD (i.e. single-vessel, two-vessel, and three-vessel disease). A p-value of < 0.05 was considered to indicate statistical significance.

3. Results

3.1. Patients

Mean heart rate during CT was 63 ± 7 bpm (41–110 bpm). Mean maximum AAA diameter was 64 ± 15 mm (42–100 mm), mean AAA length was 73 ± 35 mm (45–108 mm). 15/60 patients (25%) were clinically symptomatic, whereas 45 patients (75%) showed an AAA size growth.

3.2. Cardiovascular history and cardiovascular risk

Mean FRS estimated a 10-year risk for cardiac events of 17 ± 8% (5–43%) (Table 1).

3.3. Calcium scoring

CT calcium scoring revealed coronary calcifications in 57/60 patients (95%). Median AS was 393 (0–3538). One of three patients with no calcified plaques showed normal
coronary arteries. The other two patients had an occlusion of the right coronary artery and a non-significant stenosis of the right coronary artery caused by soft plaques.

AS-related percentiles stratified 32/60 patients (53%) as having an AS>75th percentile (Fig. 1). No significant correlation was found between AS and FRS (P=0.76). AS-related percentiles did not correlate with the FRS (P=0.85).

3.4. CT coronary angiography

Inter-observer agreement was good (κ=0.71) for image quality ratings and excellent (κ=0.86) for the detection of coronary stenoses.

846/851 segments (99%) in 57/60 patients (95%) were depicted with diagnostic image quality. 130/856 coronary segment (15%) and 2/17 bypass graft segments (11%) were classified as having significant stenoses. Stent patency was documented in two coronary segments (100%).

Twenty-seven patients (45%) had no significant coronary stenosis, 16 patients (27%) had a one-vessel CAD, 10 patients (17%) had a two-vessel CAD, and 7 patients (11%) had a three-vessel CAD. Conventional catheter angiography (CCA) confirmed significant stenosis in 11/33 patients (33%) in whom CT demonstrated significant coronary stenosis.

No significant correlation was found between the extent of CAD and FRS (P=0.55), whereas AS (r=0.43, P<0.01) and AS-related percentiles (r=0.51, P<0.001) significantly correlated with the extent of CAD (Fig. 2).

3.5. Global LV systolic function

Mean EF was 59±10% (37–73%). 55/60 patients (92%) showed an EF >50%. Significant coronary stenoses were found in five patients (100%) with a reduced EF.

3.6. Correlations of AAA size with cardiovascular risk and extent of CAD

No significant correlation was found between AAA dimensions (i.e. diameter and length) and FRS (P=0.19; P=0.58),

![Bar chart visualizing the distribution of patients based on their Agatston score (a) and the Agatston score-related percentiles normalized to age and gender (b). Analysis of the Agatston score-related percentiles showed that 53% patients were at high risk (i.e. above the 75th percentile).](image)

![Box plot showing the Framingham risk score (a) and the Agatston score (b) of patients with respect to the extent of coronary artery disease (i.e. no significant coronary artery stenosis, one-vessel, two-vessel, or three-vessel disease). Boundary of boxes indicates 25th and 75th percentile, and line within box indicates the median. Error bars indicate smallest and largest values within 1.5 box lengths. The Agatston score significantly correlated (r=0.43, P<0.01) with the extent of coronary artery disease, whereas no correlation was found for the Framingham risk score (P=0.55).](image)
4. Discussion

Accurate assessment of CAD in patients prior to AAA repair is important for optimized risk stratification and for the reduction of the peri-procedural morbidity and mortality of these patients [10]. This study shows that cardiac CT including calcium scoring and coronary angiography is feasible in patients with AAA and provides incremental information about the status of the coronary arteries beyond the assessment of traditional cardiovascular risk factors alone.

The distribution of cardiovascular risk factors in AAA patients indicates the necessity of an improved preoperative risk assessment over the assessment of traditional risk factors alone [11].

4.1. Calcium scoring

Coronary calcium scoring using CT has been used for decades as a tool for optimizing the risk stratification for the development of cardiac events [5]. In our study, the coronary calcium burden varied substantially. When applying the AS to age- and gender-related percentiles [9], 53% of our patients were at high risk for future cardiac events. Interestingly, no correlation was found between the traditional risk assessment and the AS. This fact illustrates the importance of an examination that directly visualizes the degree of CAD. This is consistent with recent data from Greenland et al. [4] who showed that the AS modified the predicted risk of cardiac events as compared to the FRS alone.

4.2. CT coronary angiography

Galland [1] demonstrated that cardiac complications are the major cause of death following elective AAA repair. Patients who initially sustained a cardiac complication were more likely to die from that problem than those who suffered other primary complications. Johnston [12] found that two-thirds of deaths following repair of non-ruptured AAA were due to cardiac events. The study also showed that patients who had a cardiac problem after their operation had a 25% mortality rate compared with 1% in those with no cardiac complications. Thus, patients with ischemic heart disease should be managed more intensively before, during, and after the operation. Fifty-five percent of our patients showed significant coronary artery stenoses. This high prevalence is in accordance to a study by Hertzer et al. [13].

In general, the diagnostic accuracy of CT coronary angiography may be hampered by heavy calcifications. This is due to blooming artifacts caused by calcifications obscuring the true vessel lumen. On the other hand, latest dual-source CT technology did not show differences with respect to the rate of segments with a diagnostic image quality in patients having a low or high coronary calcium burden [6]. Therefore, dual-source CT may still serve as a tool for noninvasive exclusion of CAD even in patients with a high AS. In our study, 99% of the coronary segments were visualized with a diagnostic image quality in 95% of the patients. Furthermore, CCA confirmed the CT diagnosis of significant coronary stenosis in one-third of our patients. For these reasons, we suggest that the diagnosis of significant coronary artery stenoses can be accurately established prior to AAA repair using CT, with the additional information from calcium scoring that can be used for risk assessment.

The AS significantly correlated with the extent of CAD. Thus, the AS may be used as a surrogate marker for the severity of CAD in patients with AAA. This is in line with data from the literature indicating that a higher AS more likely predicts stenoses than does a lower AS [5]. On the other hand, it is important to know that a negative calcium score does not allow ruling-out significant stenoses. In our study, two patients without any calcified but non-calcified plaques suffered from significant coronary stenoses.

4.3. Global LV systolic function

In general, parameters of LV function may be evaluated by magnetic resonance imaging or transthoracic echocar-
risk stratification, which also provides prognostic information for cardiac events. Nevertheless, it remains a strong predictor regarding the long-term outcome, especially in patients at an increased risk for CAD [14]. Since coronary artery imaging with CT is performed with ECG synchronization, the LV is depicted in diastole and systole and thus allows for the quantification of global LV systolic function [7]. In our study, CT showed a reduced LV EF in almost 10% of all patients.

4.4. Study limitations

First, there are various scores for stratifying the cardiovascular risk of patients. In the present paper we assessed the Framingham method and CT calcium scoring. Secondly, the study design does not allow for concluding whether to treat or not to treat a patient in order to minimize cardiac peri-operative risk. Further studies will have to show the impact of cardiac CT on the peri-operative management and how much the risk of patients is lowered. Finally, contrary to TTE and magnetic resonance imaging, CT is generally not suitable for the sole assessment of LV function because of radiation exposure to the patient and the use of contrast material. In addition, the functional significance of coronary stenoses cannot be evaluated by purely anatomical information as obtained by CT but by using functional information as obtained by cardiac magnetic resonance which also provides prognostic information for risk stratification [15].

5. Conclusions

Patients with AAA show a wide range of coronary calcium burden with the majority at high risk for cardiovascular events. The coronary calcium burden is correlated with the extent of CAD. More than 50% of the patients with AAA suffer from significant coronary stenoses which indicates the need for a preoperative coronary evaluation. Future studies are warranted to determine the impact of cardiac CT findings on patient outcome after AAA repair.

References


eComment: Re: The heart of patients with aortic aneurysms: evidence from cardiac computed tomography

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The subject of this article, in our opinion, is a highly topical issue, because despite the great advances in cardiovascular surgery and particularly in the surgical treatment of abdominal aortic aneurysm (AAA), concomitant coronary artery lesions still remain a serious problem [1].

In the 1980s great attention was paid to the detection of coronary artery lesions in patients with AAA [2]. At our center, we used to perform selective coronary angiography through the femoral or the axillary arteries, and even through the translumbar aortic approach for patients in whom AAA was accompanied by brachial artery obstruction.

Computed tomography (CT) has been successfully used for aortic aneurysm detection for a long time. A relatively recent CT-application technique for the examination of coronary arteries was sequentially tested on 16-, 32- and 64-slice CT scanners. Now this technique looks perfect [3].
Our experience of coronary arteries examination on 128-slice CT-scanner shows that such technique provides high quality diagnostic images, if all routine procedures are performed properly.

The authors of the article managed to demonstrate that the issue of a non-invasive detection of concomitant coronary artery lesions in patients with AAA might be considered to be solved.

References

