Computed tomography coronary angiography : from quantification of coronary atherosclerosis to risk stratification of patients

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Chapter 8

Feasibility of an automated quantitative computed tomography angiography-derived risk score for risk stratification of patients with suspected coronary artery disease

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American Journal of Cardiology 2014;113:1947-1955

Abstract

Purpose: Computed tomography coronary angiography (CTA) has important prognostic value. Additionally, quantitative CTA (QCT) provides a more detailed, accurate assessment of coronary artery disease (CAD) on CTA. Potentially, a risk score incorporating all quantitative stenosis parameters allows for accurate risk stratification. Therefore, the purpose of this study was to determine if an automatic, quantitative assessment of CAD using QCT combined into a CTA risk score allows risk stratification of patients.

Methods: In 300 patients QCT was performed to automatically detect and quantify all lesions in the coronary tree. Using QCT, a novel CTA risk score was calculated based on plaque extent, severity, composition and location on a segment basis. During follow-up the composite endpoint of all-cause mortality, revascularization and non-fatal infarction was recorded.

Results: In total, 10% of patients experienced an event during a median follow-up of 2.14 years. The CTA risk score was significantly higher in patients with an event (12.5(IQR8.6–16.4) versus 1.7(IQR0–8.4), $P<0.001$). Among 127 patients with obstructive CAD (≥50% stenosis), 27 events were recorded, all in patients with a high CTA risk score.

Conclusion: The present study demonstrated that a fully automatic QCT analysis of CAD is feasible and can be applied for risk stratification of patients with suspected CAD. Furthermore, a novel CTA risk score incorporating location, severity and composition of coronary lesion was developed. This score may improve risk stratification but needs to be confirmed in larger studies.

Introduction

The aim of the present study was to evaluate patients with suspected CAD undergoing CTA and: 1) perform a fully automatic quantitative assessment of coronary CTA datasets to assess the location, severity and composition of CAD, and 2) to incorporate all these variables into one risk score. Further aims were: 3) to assess the value of this integrated score for risk stratification and 4) to compare the risk classification according to this new score as compared to existing risk scores.

Methods

Patients

The population consisted of 300 patients, referred for the evaluation of (a)typical chest pain or dyspnea. Patients with previous percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG) were excluded. Clinical data were prospectively entered into the departmental Cardiology Information System (EPD-Vision©, Leiden University Medical Center, the Netherlands) and retrospectively analyzed. The Institutional Review Board of the Leiden University Medical Center approved this retrospective evaluation of clinically collected data, and waived the need for written informed consent.

CTA acquisition

Patients were scanned either with a 64-slice CT scanner (Aquilion 64, Toshiba Medical System, Otowara, Japan) or a 320-row volumetric scanner (Aquilion ONE, Toshiba Medical System, Otowara, Japan). Coronary CTA was performed according to standard clinical practice as previously described.[1] Only patients with clinical diagnostic image quality of the coronary CTA were included.

Quantitative computed tomography

QCT was performed in five automatic steps, as depicted in Figure 1.

1) The coronary tree was automatically extracted from the coronary CTA dataset.[2] Using a tree labeling algorithm, the segments of the coronary tree were automatically labeled according the American Heart Association (AHA) 17-segements model.[3;4] 2) Curved multi-planar reformations (CMPR) of each coronary vessel and side-branch were created.[2] 3) The lumen and vessel wall were automatically segmented using a previously validated software tool (QAngio CT Research Edition version 1.3.6, Medis Medical Imaging Systems, Leiden, the Netherlands).[5] 4) Coronary plaque constitution was assessed using a dedicated tissue characterization algorithm as previously

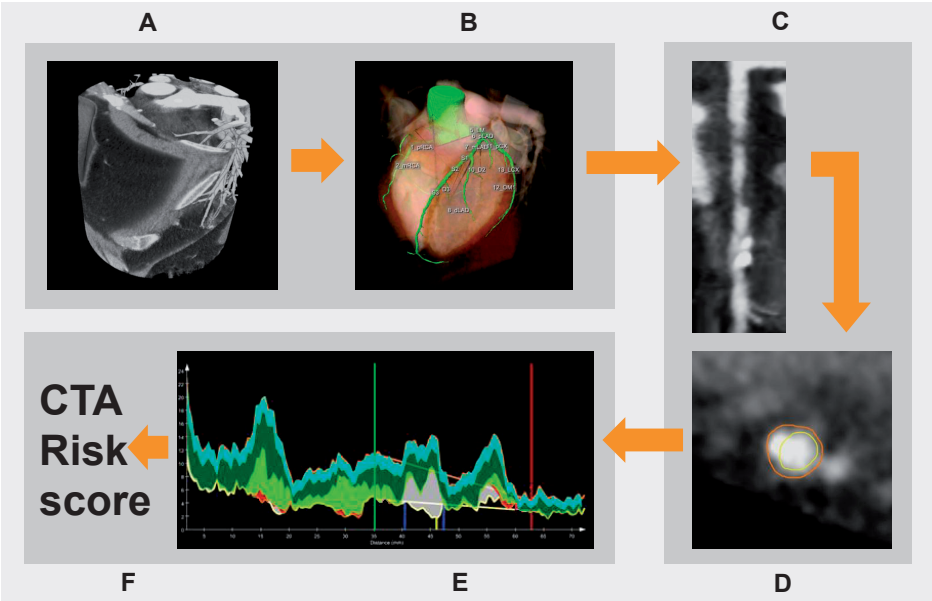


Figure 1. Schematic overview of the automatic quantitative CT algorithm.
The 3-dimensional coronary tree was extracted from the coronary CTA data set (Panel A). Using an automatic labeling algorithm the coronary tree was labeled according to the AHA 17-segment model (Panel B). Of each coronary artery a curved multiplaner reformation (CMPR) was constructed (Panel C). Next, a fully automatic detection of the lumen and vessel wall was performed (Panel D). Finally, each atherosclerotic lesion was automatically detected based on the lumen and vessel wall contours as well as the corresponding reference lines (estimate of normal tapering of the coronary artery), as shown in panel E. Stenosis parameters were calculated at the level of the minimal lumen area (MLA, vertical yellow marker). Additionally, plaque volumes and plaque types were derived for the whole coronary artery lesion, ranging from the proximal to the distal lesion marker (blue vertical markers). Fibrotic tissue was labeled in dark green, fibro-fatty tissue in light green, dense calcium in white and necrotic core in red. Finally, the CTA risk score per patient is automatically generated (Panel F).

described.[6] This tissue characterization algorithm allows for the differentiation into four different plaque types. Currently, it is unclear how this should be translated to the commonly used classification of non-calcified, partially calcified and calcified plaque. For this analysis, the percentage ratio between dense calcium (DC) and necrotic core (NC) (DC/(NC + DC)*100) was used to differentiate between partially calcified, non-calcified and calcified plaques. Lesions with a ratio <10% were considered non-calcified plaque as well as lesion without NC or DC, lesions with a ratio >75% were classified as calcified plaque. Coronary plaques with ratios ≥10% and ≤75% were classified as partially calcified plaque. 5) Coronary lesions were automatically detected. Within each segment, a regression analysis is performed on the lumen area graph to define a lumen reference line. A lesion is defined on the region surrounding the minimal lumen area (MLA) where the lumen area is smaller than this

reference. If needed, this lesion is enlarged to include calcified spots located near the MLA (within 50 mm and >1 mm^3). Lesions with negative stenosis degree and steep reference slopes (<-0.35 mm^2/mm) were removed as well as short lesions (<1.5 mm), lesions in segments with small vessel and lumen areas (<8 mm^2 and <1.5 mm^2 respectively), and distally located lesions (>150 mm from ostium).

The automatic lesion detection was confirmed by an experienced observer. The software allows the observer to override the automatic lesion detection. If needed, small adjustments were made.

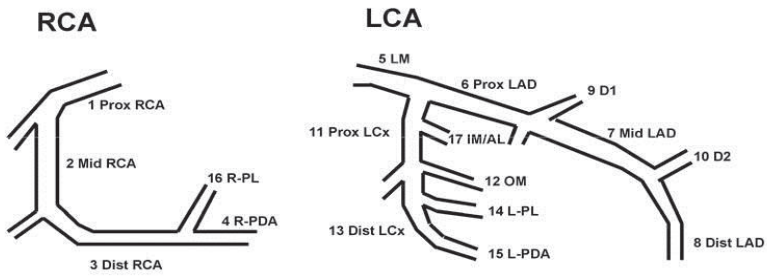
CTA risk score

A novel comprehensive risk score was created to combine the information on location, extent, severity and composition of each coronary lesion. As described in Figure 2, the score consists of three components for each segment; a segment location weight factor, a stenosis severity weight factor and a plaque weight factor. 1) The location of each lesion is represented by a segment weight factor based on the Leaman score.[4;7] A different set of weight factors is applied to left or right dominant coronary artery systems. 2) Stenosis severity was described by the stenosis severity weight factor. A previous meta-analysis reported a hazard ratio (HR) of 1.35 (1.09 – 1.67) for each significant stenosis in each segment of the coronary tree.[8] Therefore 1.4 was chosen as the weight factor for a significant stenosis (≥50% area stenosis). 3) In a study performed by Gaemperli *et al.*, stratifying the diseased segments according to plaque composition, the authors reported a HR of 1.21 (1.11 – 1.32) for segments with calcified plaques, 1.57 (1.38-1.79) for segments with partially calcified plaques and 1.71 (1.14-2.56) for segments with non-calcified plaques.[9] This was translated in the score by a weight factor of 1.2 for calcified plaque, 1.6 for partially calcified plaque and 1.7 for non-calcified plaque.

The CTA risk score is automatically calculated using QCT. When coronary plaque is absent (<30% area stenosis) the score is 0. When a stenosis is present, a score is given according to the location of the lesion in the coronary artery tree, this score is multiplied by the stenosis weight factor and multiplied by the plaque weight factor. The final score is calculated by summation of the individual segment scores (range 0-55) (Figure 2).

Modified Duke prognostic CAD index

In addition, the modified Duke prognostic CAD index was applied to the QCT results.[10;11] The score consist of 6 categories;1: <50% stenosis, 2: ≥2 stenoses 30% to 49% (including 1 artery with proximal disease or 1 vessel with 50% to 69% stenosis, 3: 2 stenoses 50% to 69% or 1 vessel with ≥70% stenosis, 4: 3 stenoses 50% to 69% or 2 vessels with ≥70% stenosis or proximal left anterior descending stenosis ≥70%,



Segment Weight Factor		
Segment	**Right Dominant**	**Left Dominant**
LM	5	6
Prox LAD	3.5	3.5
Mid LAD	2.5	2.5
Dist LAD	1	1
D1	1	1
D2	0.5	0.5
Prox LCx	1.5	2.5
Dist LCx	1	1.5
AL/IM	1	1
OM	1	1
L-PL	0.5	0.5
L-PDA	0	1
Prox RCA	1	0
Mid RCA	1	0
Dist RCA	1	0
R-PL	0.5	0
R-PDA	1	0

Stenosis Weight Factor	
<50%	1
≥50%	1.4

Plaque Weight Factor	
Calcified	1.2
Mixed	1.6
Non-Calcified	1.7

Segment(n) Score =

Plaque Weight Factor

X

Stenosis Weight Factor

X

Segment (n) Weigt Factor

CTA risk Score = Σ Segment (1-17) Score

Figure 2. Schematic overview of the CTA risk score.
The CTA risk score is calculated by the summation of the individual segment scores, which are obtained by multiplying the segment weight factor, the stenosis weight factor and the plaque weight factor.
AL: anterolateral segment; D1: diagonal 1; D2: diagonal 2; IM: intermediate segment; LAD: left anterior descending coronary artery; LCA: left coronary artery; LCx: left circumflex coronary artery; LM: left main segment; L-PDA: left posterior descending artery; L-PL: left posterolateral segment; OM: obtuse marginal segment; RCA: right coronary artery; R-PDA: right posterior descending artery; R-PL: right posterolateral segment.

5: 3 vessels ≥70% stenoses or 2 vessels ≥70% stenosis with proximal left anterior descending, 6: Left main stenosis ≥50%.Subsequently, the distribution of the novel CTA risk score within the Duke CAD categories was assessed.

Follow-up and event definition

Patient follow-up data were gathered using clinical visits or standardized telephone interviews. A composite endpoint was constructed using all-cause mortality, revascularization after 30-days and non-fatal myocardial infarction. This 30-day interval was

used to exclude coronary CTA-driven events (referral for angiography mainly based on coronary CTA findings).[12] Non-fatal myocardial infarction was defined based on criteria of typical chest pain, elevated cardiac enzyme levels, and typical ECG changes.[13]

Statistical analysis

Continuous data are presented as mean ± SD if normally distributed or as median (interquartile range, IQR) if non-normally distributed. Categorical data are presented as absolute numbers and percentages. First, the QCT parameters were compared between both patients groups (with versus without events). Second, both the novel CTA risk score and the modified Duke prognostic CAD index were compared between both groups. Third, the ability of the CTA risk score for risk stratification of patients was assessed. For this purpose, the CTA risk score was stratified into a low and high risk category based on receiver operating characteristic (ROC) curve analysis, ensuring the highest negative predictive value. First, the distribution of the risk score in patients with and without obstructive CAD (≥50% area stenosis in QCT) was assessed; and correlated to the occurrence of an event. In a similar fashion, the distribution within the Duke CAD categories was assessed. For this purpose, the Duke CAD categories were divided in three groups: Mild CAD, defined as Duke CAD category 1; Moderate CAD, defined as Duke CAD category 2-3; Severe CAD, defined by the three most severe categories. Fourth, to evaluate the independent predictive value of the CTA risk score, univariate and multivariate Cox-regression analyses were performed. All baseline or univariate significant clinical variables were entered into the multivariate model. All statistical tests were two-sided and a P-value <0.05 was considered statistically significant. All statistical analyses were performed with SPSS software (Version 20.0, SPSS Inc., Chicago, Illinois).

Results

The patient population consisted of 300 patients referred for the evaluation of chest pain during the period January 2008 - May 2010. Baseline characteristics are summarized in Table 1.The median follow-up duration was 2.14 years (IQR1.07-3.48); 28(9%) patients were lost to follow-up. During the follow-up period the composite endpoint occurred in 29 patients (event rate 10%) ; 25 (8%) patients underwent revascularization (23 PCI and 2 CABG) after 30-day of CTA acquisition. Death occurred in 4 patients (1%). In patients with an event, mean age was higher and diabetes and hypertension were more often prevalent.

Table 1. Patient characteristics.

		Event		
Variable	Total (300)	No (N=271)	Yes (N=29)	P- value
Age (years)	55±11.5	54±11.6	60±8.5	**<0.001**
Men	180(60%)	161(59%)	19(66%)	0.526
Diabetes Mellitus	90(30%)	76(28%)	14(48%)	**0.024**
Hypertension†	111(37%)	95(35%)	16(55%)	**0.034**
Hypercholesterolemia‡	100(33%)	88(32%)	12(41%)	0.334
Smoker	52(17%)	47(17%)	5(17%)	0.988
Obesity*	56(19%)	49(18%)	7(24%)	0.432
Calcium score	146±420 1(0–86)	118±388 1(0-54)	407±596 148(30-514)	**<0.001**

Data are represented as mean ± SD, median (interquartile range) or as number and percentages of patients.
†Defined as systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mmHg or the use of antihypertensive medication.
‡Defined as serum total cholesterol ≥230 mg/dL or serum triglycerides ≥200 mg/dL or treatment with lipid lowering medication.
* Defined as a body mass index of ≥ 30 Kg/m^2

QCT characteristics

The results of the QCT lesion analysis on a patient basis are depicted in Table 2. In patients with an event, significant obstructive lesions were more frequently observed. Furthermore, in patients with an event the mean number of partially calcified or calcified lesions was higher compared to patients without events.

Table 2. Comparison of quantitative computed tomography coronary angiography results between patients with and without events.

	Event		
Variable	No (N=271)	Yes (N=29)	P-value
No of plaques ≥30%	1.54±2.14	3.83±2.04	**<0.001**
No of plaques 30-50%	0.82±1.17	1.45±1.12	**<0.001**
No of obstructive lesions ≥50%	0.51±0.87	1.83±0.97	**<0.001**
No of severe lesions ≥70%	0.17±0.92	0.69±1.07	**<0.001**
No of calcified lesions	0.95±1.67	2.66±2.10	**<0.001**
No of partially calcified lesions	0.31±0.73	0.76±0.87	**<0.001**
No of non-calcified lesions	0.29±0.60	0.41±0.63	0.189

Table 2. (Continued)

	Event		
Variable	No (N=271)	Yes (N=29)	P-value
No of narrowed coronary arteries	0.51±0.87	1.83±0.97	**<0.001**
Left main lesion	6(2%)	4(13%)	**0.001**
Right coronary artery lesion	45(16%)	11(37%)	**0.005**
Left anterior descending artery lesion	63(23%)	24(82%)	**<0.001**
Left circumflex artery lesion	25(9%)	13(44%)	**<0.001**
Lesions in proximal segments	0.34±0.68	1.07±1.0	**<0.001**
Lesions only in distal segments	0.38±0.89	1.31±1.17	**<0.001**
Percentage of proximal lesions	52±37	48±37	0.961

CTA risk score

In the overall population, the median CTA risk score was 3.0(IQR0.0-9.8). The median CTA risk score was significantly higher in patients with an event as compared to event-free patients (12.5(IQR8.6–16.4) versus 1.7(IQR0–8.4), P<0.001). Accordingly, in patients with a CTA risk score of 0, the event rate was <1% (1 of 130). Based on ROC curve analysis, a CTA risk score of 7 was defined as a cut-off value between low and high CTA risk score to ensure the highest negative predictive value. Figure 3 provides a patient example of the QCT analysis. The distribution of patients with a high and low CTA risk score between patients with and without obstructive CAD is depicted in Figure 4. Of interest, in the 112 patients with obstructive CAD, all events occurred in patients with a high CTA risk score.

Reclassification according to the presence of obstructive CAD and modified Duke prognostic CAD index

The results of the modified Duke prognostic CAD index calculation based on the QCT results are summarized in Figure 5. The majority of the patients were categorized in Duke CAD category 1. Indeed, all events in patients within Duke CAD category 2 or 3 occurred in patients with a high CTA risk score. Only one event occurred in a patient with a low CTA risk score, this patient was classified in Duke CAD category 1.

Cox-regression analysis

In the univariate Cox-regression analysis (Table 3), age and CTA risk score were significantly associated with the occurrence of an event. In the multivariate analysis, adjusted for significant baseline characteristics, the CTA risk score was independently associated with events.

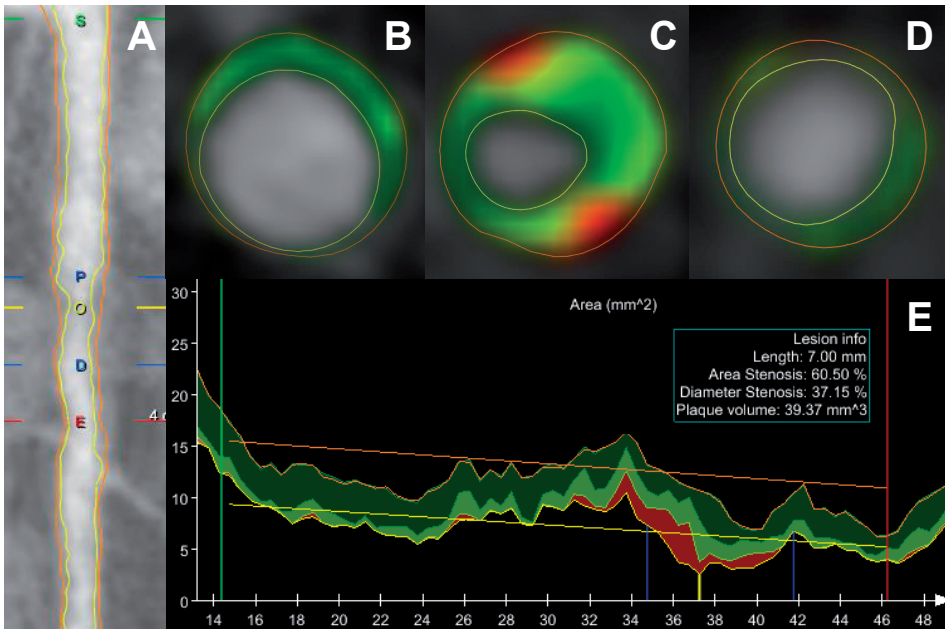
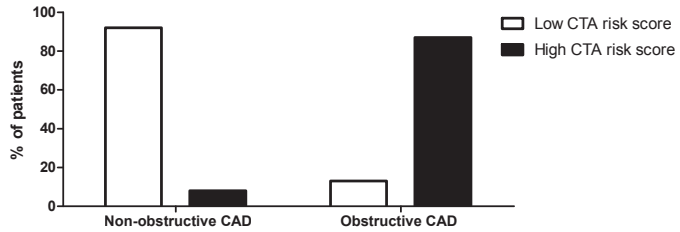


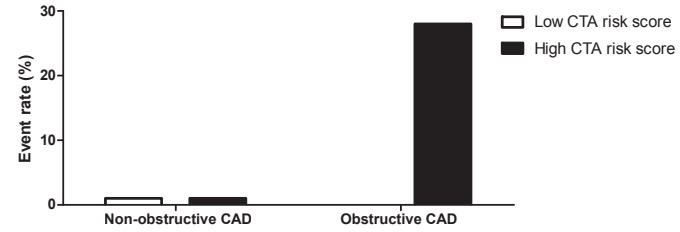
Figure 3. Patient example of the QCT analysis.
An example of a 54-year old man with a CTA risk score of 8.3. Panel A shows the MPR of the LAD of this patient in which a significant non-calcified plaque was present. In panel C, the cross-section at the minimal lumen area with corresponding proximal and distal reference regions is shown (Panels B and D). The lesion was automatically detected and quantified (panel E) by the algorithm as depicted in Figure 1. The stenosis degree was 61% and the lesion was characterized as non-calcified plaque. Three months after the coronary CTA, the patient underwent invasive coronary angiography for progressive chest pain, followed by PCI of the LAD.

Discussion

The present study assessed the feasibility of a novel, fully automatic QCT algorithm to quantify the location, severity and composition of coronary artery atherosclerosis on a patient basis. Particularly, differences in QCT derived CAD parameters were shown between patients with and without subsequent events. Second, a novel CTA risk score was developed, enabling to express the location, extent, severity and composition of CAD in a number for each individual patient. This score was significantly higher in patients who experienced an adverse event. Finally, the distribution of the CTA risk according to the presence of obstructive CAD and within the Duke CAD score categories was established.



No of patients	188	112
Low CTA risk score	173(92%)	15(13%)
High CTA risk score	15(8%)	97(87%)



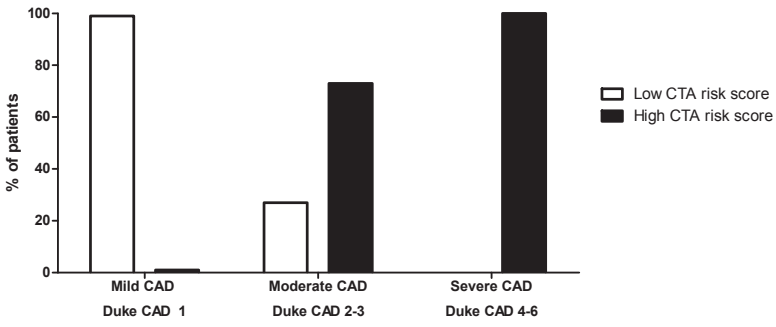
Events	2	27
Low CTA risk score	1(1%)	0(0%)
High CTA risk score	1(1%)	27(28%)

Figure 4. Distribution of the CTA risk score according to the presence of a significant stenosis.
Upper panel: Bar graph representing the distribution of patients with a low or high CTA risks score. Lower panel: Bar graph representing the event rates in patients with a low or high CTA risk score in patients with and without obstructive CAD. In the patients with obstructive CAD, all events occurred in patients with a high CTA risk score.

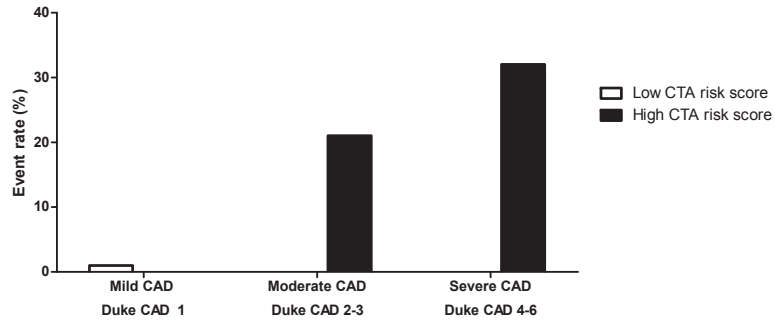
Quantitative computed tomography coronary angiography (QCT)

The assessment of CAD on CTA images is mainly performed visually. However, the accuracy and reproducibility of visually analysed CTA images is limited.[14] This may result in misclassification of obstructive or non-obstructive CAD; for example, in the multi-centre ACCURACY study a visually assessed obstructive CAD on CTA was confirmed in only 64% of patients using quantitative coronary angiography (QCA).[15]

These observations underscore the need for a robust, reproducible method for quantification of CAD on CTA. Novel software tools have been designed allowing quantitative assessment of CTA datasets similarly to QCA.[5;6;16;17] Leber *et al.* performed a quantitative analysis of CAD on CTA and compared the results to ICA and IVUS.[17] In total, 798 segments were analyzed, illustrating a clear relation between plaque burden as quantified on CTA and IVUS. However, for quantification of stenosis severity only modest correlations between CTA and ICA were shown. Voros *et al.* included 50



No of patients	163	96	41
Low CTA risk score	162(99%)	26(27%)	0(0%)
High CTA risk score	1(1%)	70(73%)	41(100%)



Events	1	15	13
Low CTA risk score	1(1%)	0(0%)	0(0%)
High CTA risk score	0(0%)	15(21%)	13(32%)

Figure 5. Distribution of the CTA risk score according to the grouped Duke CAD category.
Upper panel: Bar graph representing the distribution of patients with a low or high CTA risk score in the three groups. In the patients with mild CAD, a large proportion of patients (73%) were reclassified by a high CTA risk score.
Lower panel: Bar graph representing the event rates in patients with a low or high CTA risk score in the three Duke CAD groups. In the patients with Duke CAD category 2- 3, all events occurred in patients with a high CTA risk score.

patients who underwent cardiac CTA, ICA and IVUS.[16] In this study, stenosis severity as derived from QCT correlated well with stenosis severity on QCA. Moreover, QCT and IVUS correlated significantly in the assessment of lumen and vessel area. These different findings between the study by Leber *et al.*[18] and Voros *et al.*[16], can be explained by the fact that Voros *et al.* used an automated method for assessment of the coronary artery lumen and vessel wall. The reproducibility of QCT has also been

Table 3. Univariate and multivariate Cox-regression analysis for the prediction of events.

Variable	Univariate HR (95%CI)	P-value	Multivariate HR (95%CI)	P-value
Age	1.05(1.01;1.09)	**0.008**	1.02(0.98;1.07)	0.238
Gender	1.30(0.61;2.80)	0.499		
Diabetes Mellitus	1.86(0.90;3.86)	**0.095**	2.02(0.95;4.29)	0.067
Hypertension	2.13(1.02;4.42)	**0.044**	1.07(0.48;2.38)	0.866
Hypercholesterolemia	1.19(0.57;2.50)	0.640		
Family history of CAD	1.41(0.68;2.92)	0.354		
Smoking	0.95(0.36;2.48)	0.910		
Obesity	1.41(0.60;3.29)	0.432		
CTA risk score	1.12(1.07;1.16)	**<0.001**	1.10(1.01;1.15)	**<0.001**

CAD: coronary artery disease; CI: confidence interval; CTA: computed tomography angiography; HR: hazard ratio

addressed by Papadopoulou *et al.* illustrating high inter- and intra-observer agreement for assessment of geometrical measurements of coronary atherosclerosis [19]

Quantitative assessment of coronary artery atherosclerosis and plaque constitution is clinically relevant. Versteylen *et al.* performed a semi-quantitative analysis of CTA data and demonstrated that the 21 patients who developed an ACS more often presented with larger (non-calcified) plaque volumes and higher plaque burden as compared to control patients.[20] Importantly, the authors demonstrated incremental predictive value of semi-quantitative coronary CTA analysis over visual CTA interpretation and Framingham risk score.

For complete analysis of coronary artery atherosclerosis, not only quantitative analysis of stenosis severity and plaque burden is needed but also assessment and quantification of plaque constitution. Earlier studies have shown the agreement between plaque constitution on QCT as compared with IVUS Virtual Histology (IVUS VH). Brodoefel *et al.* compared QCT and IVUS VH in 22 coronary lesions, showing good correlations for assessment of overall plaque volume and non-calcified plaque volume, but the agreement between the 2 techniques for assessment of plaque constitution was limited.[21] The more sophisticated software for quantification of plaque constitution that was used in the current study has been shown to correlate well with IVUS VH in 57 patients (108 coronary lesions).[6] Particularly, distinction and quantification of coronary plaque volume and plaque constitution is feasible with this software.

Novel CTA risk score

In the present study, a novel CTA risk score was developed. This score consists of three components per coronary lesion (i.e. plaque location, severity and composition).

Each component has been demonstrated to provide important prognostic information for risk stratification of patients with CAD.

Stenosis location. The location of a coronary atherosclerotic lesion has important prognostic value. Patients with lesions located proximally in the coronary arteries have a worse prognosis as compared to patients with distally located lesions.[10] In the early 1980s, the Leaman score was developed to provide weight factors for each segment in the coronary artery tree based on the amount of myocardium at risk per coronary segment.[7] This score was thereafter implemented in the angiographic SYNTAX-score, designed to quantify the complexity of CAD and its value has been established in clinical studies.[22-24] The same Leaman weight factors were directly incorporated in the novel score used in the present study.

Stenosis severity. Currently, the assessment of CAD on coronary CTA is mainly targeting the detection or exclusion of obstructive CAD. However, the presence of non-obstructive CAD on coronary CTA is also associated with worse prognosis. In the CONFIRM registry, Chow *et al.* demonstrated a 3-fold increase in annual mortality rate for patients with non-obstructive CAD as compared to patients without atherosclerosis.[25] To account for the clinical value of atherosclerotic burden and non-obstructive CAD, previously proposed scores have focused on the number of lesions and the extent of CAD. Min *et al.* for example applied the Duke modified CAD index to CTA images.[16] In this score, patients were categorized according to the extent of CAD. The prognostic value of these scoring systems has recently been reported.[10;26] However, in these scores only rough estimates are implemented, whereas in the present CTA risk score established values from literature were applied per coronary segment.[8]

More recently, a novel score was designed based on the CONFIRM data.[27] This score combines both clinical and CTA data. Similar to the CTA risk score, more weight is assigned to proximal lesions. In contrast, in the CONFIRM score non-calcified plaque was not incorporated, whereas in the CTA risk score this score was weighted a higher risk than calcified plaque.

Plaque constitution. Next to assessment of stenosis severity, CTA permits assessment of plaque constitution, which provides additional prognostic value; Hou *et al.* showed in 4,425 patients that the presence of partially calcified and non-calcified plaques was associated with worse prognosis as compared to calcified plaques.[28] These results may suggest that non-calcified and partially calcified plaques represent a more vulnerable stadium of CAD, whereas calcified plaques may reflect more stable CAD. To account for this difference in prognosis, in the present score, different weight factors were applied for the different plaque constitutions.

Limitations

Some limitations need to be considered. The current evaluation should be considered a feasibility study, to demonstrate the potential use of QCT, and to introduce the concept of a novel CTA risk score. Further studies in larger populations are needed to confirm the current observations. In addition, although QCT was automatically performed, still limited user input was needed to confirm the automatic lesion detection, which may potentially have introduced observer bias. Moreover, only scans with clinical diagnostic image quality were included.

Conclusion

The CTA risk score only includes CTA derived information and no details on patients risk factors or symptoms. For clinical decision making the risk score should be considered in combination with the patients history.

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