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Clinical impact of CT coronary angiography without exclusion of small coronary artery segments: a real-world and long-term study

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ABSTRACT

Objectives CT coronary angiography (CTCA) has become a valuable diagnostic test in the workup of patients with possible coronary artery disease (CAD). Because of inherent limitations in spatial resolution, epicardial vessels with a small diameter, in general less than 1.5–2 mm, have so far been excluded in studies assessing clinical utility of CTCA. This study sought to assess the clinical impact of CTCA taking into account pathology in small coronary arteries.

Methods We conducted a retrospective cohort study of all patients with possible CAD who underwent dual-source CTCA and subsequent invasive coronary angiography (ICA) between January 2010 and July 2017. Patients with an Agatston calcium score ≥1000 were reported separately. Diagnostic accuracy of CTCA on a patient, vessel and segment level was calculated. The physician's therapeutic decision was defined as conservative, medical antianginal treatment or revascularisation. Using ICA as the reference, we calculated the precision of CTCA to replicate these therapeutic recommendations.

Results In total, 1209 patients underwent both CTCA and ICA. Overall diagnostic performance of CTCA showed a sensitivity of 90% (95% CI 86% to 93%) and specificity of 40% (95% CI 36% to 45%). With regard to clinical decision making, CTCA showed good performance: 91% of patients who were treated medically or by revascularisation were correctly identified. Prevalence of disease in small vessel segments was low: 16% showed significant CAD on ICA. Prevalence of significant disease was 70% in patients with an Agatston score ≥1000: the majority underwent revascularisation.

Conclusions From a true patient perspective, without exclusion of smaller coronary artery segments, CTCA allows safe patient management.

Key questions

What is already known about this subject?

- CT coronary angiography (CTCA) has become a valuable diagnostic test in the workup of patients with possible coronary artery disease (CAD) and is increasingly being used for this purpose as a first-line test in lieu of traditional noninvasive stress tests. CTCA is considered the ideal gatekeeper for invasive coronary angiography (ICA), although an entire assessment of the epicardial coronary tree, as we are used to obtain when performing ICA, has never been reported with CTCA.

What does this study add?

- In this study, we provide a complete patient analysis without arbitrary exclusion of coronary artery segments deemed too small to have impact on clinical management. We observed that CTCA is able to identify >90% of the patients in need of medical treatment and/or revascularisation because of severe CAD. Diagnostic performance of contemporary CTCA restricted to the small vasculature remains insufficient when compared with ICA. However, the prevalence of relevant CAD in these small vessel segments is low, around 15%, and only a small minority, less than 5%, need treatment with antianginal drugs or revascularisation.

How might this impact on clinical practice?

- From a true patient perspective, CTCA in general allows safe patient management. The prevalence of significant CAD limited to the small vasculature is low but not negligible. Due to persistent limits in spatial and temporal resolution of CTCA, ICA will remain necessary for the accurate detection and specific treatment of patients with small vessel disease.

INTRODUCTION

CT coronary angiography (CTCA) has become a valuable diagnostic test in the workup of patients with possible coronary artery disease (CAD).[1] Based on recent guidelines and considering the results of two recent large randomised studies, CTCA can be used as a first-line test in lieu of traditional noninvasive stress tests for assessing symptoms suspected of CAD.[2–5] It is of critical importance to remember that an entire assessment of the epicardial coronary tree, as we are used to obtain when performing invasive coronary angiography (ICA), has never been reported with CTCA. Because of inherent limitations

Table 1 Reasons for patient exclusion

Exclusion criteria	No of patients
Previous percutaneous coronary intervention	68
CABG	41
Chronic kidney disease	12
No contrast administered	14
Extravasation of contrast	1
Calcium artery calcium score ≥1000	200
Heart transplantation	6
Congenital heart diseases	3
Irregular heart rate	17
Arrhythmogenic right ventricular dysplasia	1
BMI >40 kg/m^2	1
Pericarditis	1
CTCA in context of CABG or stent study	18
Total	383

BMI, body mass index; CABG, coronary artery bypass grafting; CTCA, CT coronary angiography.

in spatial resolution as compared with ICA, epicardial vessels with a small diameter, in general less than 1.5 or 2 mm, have so far been excluded in research studies when assessing clinical utility of CTCA.

This study sought to assess the clinical impact of possible pathology in small coronary artery segments. Clinical impact was defined as the therapeutic decision that was installed by the treating physician, based on the information provided by ICA.

METHODS

Patient selection

Study design and patient population

We conducted a retrospective study of all consecutive patients with possible CAD who underwent dual-source CTCA and subsequent ICA between January 2010 and July 2017. Of the possible 5438 patients who underwent a cardiac CT scan, we withheld 1209 individuals who underwent ICA within 3 months of the index CT scan. Patients with previous percutaneous coronary intervention (PCI) or coronary artery bypass graft surgery (CABG) were excluded. Patients with an Agatston calcium score ≥1000 were not withheld for a direct comparison but reported as a separate group. The reasons for patient exclusion are summarised in table 1. We performed an analysis of the whole coronary artery tree using the modified American Heart Association (AHA) classification,[6] including vessels with a diameter smaller than 1.5 mm. Relevant CAD was defined as the presence of anatomically significant disease on ICA, defined as a lumen diameter reduction of ≥50%. Diagnostic accuracy of CTCA on a patient, vessel and segment level was calculated. To analyse the impact of possible small vessel pathology on clinical decision making, we divided the coronary arteries into large-vessel and small-vessel segments. AHA vessel segments 1, 2, 3, 5, 6, 7, 8, 11, 13 and 17 were defined as large, segments 4, 16, 9, 10, 12, 14 and 15 were defined as small. The physician's therapeutic decision was fundamentally based on the findings of ICA and defined as conservative, medical antianginal treatment or revascularisation using PCI or CABG. In accordance with clinical guidelines, the decision to revascularise or not incorporated the demonstration of anatomical significant disease on ICA with the demonstration of myocardial ischaemia as obtained from noninvasive or invasive functional tests.[7] Using the physician's therapeutic decision as the reference, we calculated the precision of CTCA to identify the patients in need of antianginal drug therapy and/or revascularisation. In particular, we analysed whether pathology present in small coronary artery segments would be undetected by CTCA and unfavourably affect the subsequent clinical course of patients.

Clinical classification

Patients were classified according to angina type. Typical angina is defined as retrosternal discomfort, provoked by exercise or emotional stress and relieved with rest or nitroglycerin. Atypical angina is defined by only two out of the previous criteria. Non-cardiac chest pain corresponds at only one of the previous criteria, or other symptoms. ST-depressions on exercise electrocardiography without symptoms, is categorised as silent ischemia. Patients without symptoms but investigated based on risk factors or who are unable to perform an exercise test are classified as non-cardiac chest pain or asymptomatic.

Imaging procedures and interpretation

CT coronary angiography

All patients were scanned using a dual-source CT scanner (Somatom Definition Flash, Siemens). Beta-blockers were administered to all patients in case of a heart rate above 70 beats per minute. All patients received nitrates sublingually. Prior to administering contrast, a calcium scan was performed. A Coronary Artery Calcium Score (CACS) was calculated by the Agatston method.[8] Whenever the CACS exceeded 1000, a contrast scan was not performed. Intravenous contrast (70 mL Omnipaque 350) was administered at 6 mL/s, followed by 40 mL 0.9% saline flush. CTCA images were acquired with prospective ECG gating (70%), high-pitch single heartbeat acquisition, retrospective mode or a combination as needed to obtain diagnostic image quality. Tube current was 150–300 mA and voltage 80–100 kV.

All scans were analysed by a joint reading of a cardiologist and radiologist prior to the performance of ICA, in accordance with the Society of Cardiovascular Computed Tomography (SCCT) guidelines.[9] Each coronary artery segment was assessed for the presence of CAD using the modified (the intermediate branch, when present, was classified as segment 17) AHA 17-segment system[6] and classified using the Coronary Artery Disease Reporting and Data System (CAD-RADS) reporting system.[10] This

score ranges between 0 (absence of stenosis) and 5 (total occlusion of the arterial segment).

Image quality was evaluated on a per-segment basis and classified as good (defined as absence of any image-degrading artefacts related to motion, calcification or noise), adequate (presence of image-degrading artefacts but evaluation possible with moderate confidence) or poor (presence of image-degrading artefacts and evaluation possible only with low confidence). In segments that were 'unevaluable,' forced reading was performed, and readers provided their 'best-educated guess'.

Radiation doses were recorded as the dose-length product and the effective radiation dose calculated using the effective dose conversion factor of 0.014 mSv/mGy*cm, as well as the recently published 0.026 mSv/mGy*cm conversion factor.[11]

Invasive coronary angiography

Coronary angiograms were subdivided using the previously mentioned segmentation model[6] and scored for stenosis severity using the same CAD-RADS categories as used for CTCA. A stenosis was considered significant if causing a ≥50% diameter reduction. The effective radiation dose in millisievert was calculated by multiplying the dose area product with the conversion factor of 0.00023.[12]

Statistical analysis

Statistical analysis was performed using SPSS, V.24.0. Continuous variables were expressed as mean±SD, and categorical variables as percentages. Diagnostic performance of CTCA with ICA as the standard of reference is presented as sensitivity, specificity, positive and negative predictive values (PPV and NPV) with corresponding 95% CIs. Comparison between CTCA and ICA was performed on three levels: segment based, vessel based and patient based. We calculated the diagnostic OR to compare diagnostic performance when assessing large vessels versus small vessels. The physician's therapeutic decision was based on the findings of ICA and defined as conservative, medical treatment or revascularisation. Using ICA findings as the reference, we calculated the precision of CTCA to replicate these therapeutic recommendations.

Patient and public involvement

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

RESULTS

Of the 1209 patients who underwent both CTCA and ICA, 383 were excluded from the main analysis. Patients with a CACS ≥1000 were not withheld for a direct comparison but reported as a separate group. Table 2 shows the demographic characteristics for the remaining 826 patients. The mean age was 62 years. Most patients were classified as having atypical angina or non-cardiac chest pain. A minority (8%) presented with typical angina. The pretest probability of having relevant CAD was in the low-to-intermediate range, which corresponds to an appropriate selection of patients to undergo assessment by CTCA.[13 14] The data characteristics as obtained by CTCA and ICA are shown in table 3.

Table 2 Patient characteristics

Characteristic	Value
Age (years), mean (SD)	62 (9)
Female; male	265; 561
Caucasian; other	818; 8
Length (cm), mean (SD)	171 (9)
Weight (kg), mean (SD)	80.5 (14.4)
BMI (kg/m^2), mean (SD)	27.4 (4.3)
Risk factors	
Smoking	297 (36%)
Hypertension	397 (48%)
Dyslipidaemia	521 (63%)
Diabetes	107 (13%)
Family history of CAD	325 (40%)
Angina type	
Typical	67 (8%)
Atypical	185 (22%)
Silent ischaemia	73 (9%)
Non-cardiac chest pain or asymptomatic	501 (61%)
Prediction model according to Genders *et al* to assess pretest probability of CAD	26%

Prediction model according to Genders *et al*.[13]
BMI, body mass index; CAD, coronary artery disease.

Overall diagnostic performance, with inclusion of small-vessel segments

The per-patient overall diagnostic performance of CTCA, including vessel segments with a small diameter, is summarised in figure 1. Diagnostic performances measures varied in function of the image quality. For those with good image quality, we found a diagnostic accuracy (with 95% CIs) as follows: sensitivity 92% (88% to 94%), specificity 39% (35% to 44%), PPV 52% (50% to 54%), NPV 87% (82% to 91%). Those with reasonable and poor image quality showed following metrics: sensitivity 95% (77% to 100%) and 57% (34% to 77%), specificity 54% (25% to 81%) and 48% (29% to 68%), PPV 78% (66% to 86%) and 48% (36% to 61%), NPV 88% (49% to 98%) and 57% (41% to 70%). As expected, stenoses were more prevalent based on CTCA as compared with ICA. The distribution of CAD across the coronary tree is shown in table 4.

'Traditional' diagnostic performance, excluding small-vessel segments and subsequent patient management

Figure 1 summarises the diagnostic performance of CTCA when limiting the assessment to the main coronary artery

Table 3 CTCA and ICA characteristics

Characteristics	Value
CTCA	
Image quality	
Poor	50 (6.1%)
Reasonable	35 (4.2%)
Good	741 (89.7%)
Technique	
Flash	749
Retrospective (spiral CT)	31
Step-and-shoot	46
Tube voltage, median	120
Total DLP (mGy cm), mean, (95% CI)	249 (219 to 279)
Effective dose (mSv), mean, (95% CI)*	3.49 (3.07 to 3.90) or 6.48 (5.71 to 7.25)
Heart rate before scan (bpm), mean, (95% CI)	61 (61 to 62)
Heart rate after scan (bpm), mean, (95 CI)	57 (57 to 58)
Beta-blocker use	469 (57%)
Agatston score	
Total score, median, (IQR)	170 (351)
Volume calcium score, median, (IQR)	180 (310)
Calcium mass score, median, (IQR)	54 (110)
ICA	
Contrast volume (mL), mean, (95% CI)	189 (183 to 194)
Total DAP (Gyx cm^2), mean, (95% CI)	62.53 (58.39 to 66.67)
Effective dose (mSv), mean, (95% CI)	14.4 (13.4 to 15.3)
Clinical management	
Conservative	377
Medical therapy	189
PCI	180
CABG	56
Other	24

Other includes: cardiac valve or structural heart surgery (n=11), additional workup (n=10), referral for electrophysiology (n=2), contra-indication for PCI because of allergy (n=1).
*Effective dose calculated using conversion factor 0.014 mSv/mGy*cm and 0.026 mSv/mGy*cm.
CABG, coronary artery bypass grafting; CTCA, CT coronary angiography; DAP, dose area product; DLP, dose length product; ICA, invasive coronary angiography; PCI, percutaneous coronary intervention.

segments. These performance metrics resemble those of the overall patient analysis. When analysing the data on a per-vessel basis, CAD was mainly distributed in the left anterior descending and right coronary artery (table 5). Diagnostic accuracy was excellent, but not perfect, for the left main coronary artery segment. Table 6 summarises the subsequent therapeutic management. Of the 279 patients who needed medical antianginal therapy or revascularisation, 91% had relevant disease on CTCA. Of the 232 patients who underwent revascularisation, 92% could be identified with CTCA.

Diagnostic performance and subsequent patient management focusing on small coronary artery segments

Figure 1 summarises the diagnostic performance of CTCA when limiting the assessment to small coronary artery segments. As expected, performance metrics were remarkably inferior as compared with the analysis of the large-vessel segments only. Prevalence of disease was substantially lower (16% vs 40%). The therapeutic management in case of significant disease in those small vessel segments is summarised in table 6. Revascularisation was needed in four patients: CTCA identified all individuals who needed PCI of small-vessel segments.

Of note, 136 patients demonstrated non-significant CAD in small coronary artery segments. Disease was depicted more often with CTCA as compared with ICA, which explains why patients were prescribed more frequently drug therapy based on the CTCA results (11 vs 6 patients, respectively, data not shown).

We found following diagnostic ORs with corresponding 95% CIs when assessing large vessels and small vessels separately: 5.86 (95% CI 3.97 to 8.65) for large vessels and 3.13 (95% CI 2.04 to 4.81) for small vessels, respectively. The higher diagnostic OR for large vessels indicates better discriminating test performance, meaning lower incidence of false positives and false negatives on average.

Disease prevalence and therapeutic management in patients with a CACS ≥ 1000

Here, we describe the data of the 200 patients who did not undergo a contrast CT scan because of a CACS ≥1000 (table 7). The mean CACS in this group was 1782, with a range between 1000 and 9703. This patient group showed a high prevalence of significant disease on ICA. The majority of these patients, as high as 53%, underwent revascularisation.

DISCUSSION

This study reports on the clinical use of latest-generation CTCA in the real world and is unique in several ways. Most importantly, we provided a complete patient analysis without arbitrary exclusion of coronary artery segments deemed too small to have impact on clinical management. Second, recognising the fact that in clinical practice ICA remains essential to guide patient management, also in patients with rather atypical symptoms, we were able to assess diagnostic accuracy in patients with a low-to-intermediate pretest likelihood in whom it was deemed necessary on clinical grounds and not for study purposes to perform ICA after CTCA. Third, we provide clinical data on patients with an elevated CACS, who according to good clinical practice did not undergo a contrast scan.

The major findings of this study are the following:

1. With regard to clinical management, CTCA in general showed good performance to replicate the therapeutic

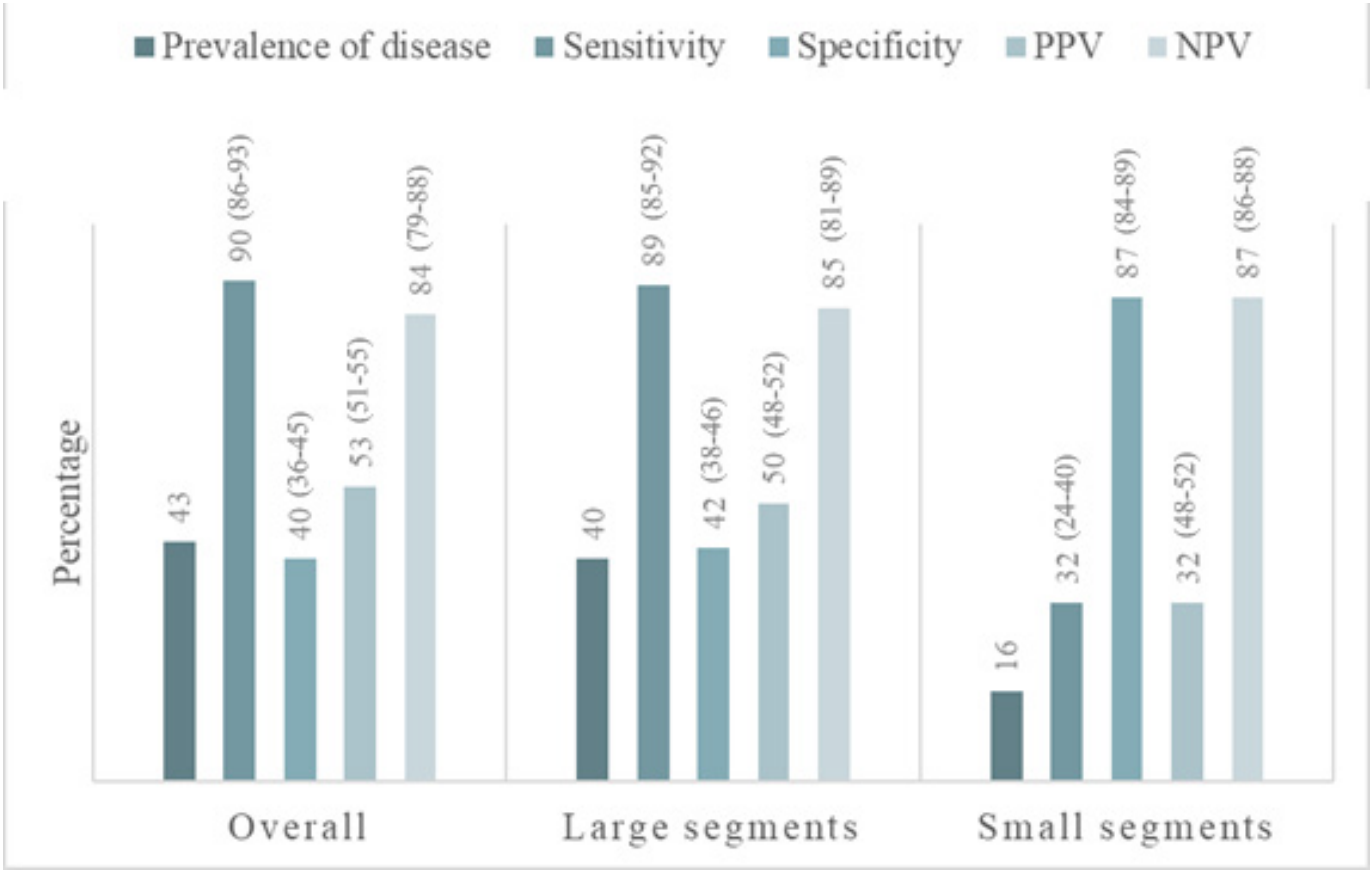

Figure 1 Prevalence of disease and diagnostic performance (with corresponding 95% CI between brackets) of CTCA for the detection of ≥50% stenosis on ICA: overall patient-based analysis, analysis focusing on large vessel segments and small coronary artery segments only. CTCA, CT coronary angiography; ICA, invasive coronary angiography; NPV, negative predictive value; PPV, positive predictive value.

Table 4 Distribution of CAD across the coronary tree

Segment analysis	Value
CTCA	
>50% stenosis, any patient	600 (72.6%)
Single vessel	306
Multivessel (excluding left main)	210
Left main-only	23
Left main disease +other vessels	61
ICA	
>50% stenosis, any patient	357 (43.2%)
Single-vessel	227
Multivessel (excluding left main)	102
Left main-only	9
Left main disease +other vessels	19

Multivessel disease is defined as significant CAD in at least two of the three major coronary artery vessels, that is, right coronary artery, left anterior descending coronary artery or circumflex coronary artery.
CAD, coronary artery disease; CTCA, CT coronary angiography; ICA, invasive coronary angiography.

recommendations as formulated after ICA for the large majority of patients.
2. As expected, prevalence of significant CAD in small-vessel segments is rather low. The need for treatment with antianginal drugs or revascularisation in this clinical scenario is below 5%.
3. The overall diagnostic performance of dual-source CTCA, without exclusion of small coronary artery segments, showed following metrics: 90% sensitivity, 40% specificity, 53% PPV, 84% NPV.
4. Patients with CACS ≥1000 showed a high prevalence of significant CAD on ICA. The majority of these patients needed revascularisation.

CTCA and patient management

The patients selected to undergo CTCA do fit the recommendations of clinical guidelines. For the majority of the 5438 patients, a CTCA without additional ICA was sufficient to guide subsequent clinical management. The patients who are the subject of this report and in whom ICA was required to direct further management, fitted the criterium of 'intermediate pretest probability', more precisely 26%, and had a disease prevalence of 43%.

Table 5 Diagnostic performance of CTCA, excluding small coronary artery segments, for the detection of ≥50% stenosis on ICA

	Prevalence of disease, %	N	TP	FP	FN	TN	Sens, %	Spec, %	PPV, %	NPV, %
Overall	40	826	292	289	36	209	89 (85–92)	42 (38–46)	50 (48–52)	85 (81–89)
Right coronary artery	12	826	70	146	27	583	72 (62–81)	80 (77–83)	32 (28–37)	96 (94–97)
Left main coronary artery	3	826	27	58	1	740	96 (82–100)	93 (91–94)	32 (26–38)	100 (99–100)
Left anterior descending coronary artery	29	826	192	276	43	315	82 (76–86)	53 (49–57)	41 (39–44)	88 (85–91)
Circumflex coronary artery	9	826	43	121	34	628	56 (44–67)	84 (81–86)	26 (22–31)	95 (93–96)

Values in parentheses represent upper and lower bound for 95% CI.
CTCA, CT coronary angiography; FN, false-negative; FP, false-positive; ICA, invasive coronary angiography; NPV, negative predictive value; PPV, positive predictive value; sens, sensitivity; spec, specificity; TN, true negative; TP, true positive.

As opposed to the somewhat artificial boundaries of the research environment, assessment of the true clinical performance of CTCA in day-to-day clinical practice, necessitates the inclusion of small vessel segments. A small vessel diameter together with extensive vessel calcifications are the two main predictors of diagnostic inaccuracy on CTCA.[15] Recently published major clinical studies systematically excluded vessels with a diameter smaller than 1.5 or 2 mm.[4 5 16] Severely calcified vessels make it impossible to assess the degree of coronary stenosis and most experts would agree on a certain threshold level of calcium above which it is advisable not to proceed with a contrast scan.[3 16] In our study, we used an CACS ≥1000 as exclusion criterion. Within these boundaries of vessel calcification, we performed an 'intention-to-diagnose' analysis, allowing to formulate clinical management on a true patient level. In the clinical situation where an ICA is deemed necessary, the management plan is fundamentally based on these findings. The setup of our study makes it therefore feasible to make a head-to-head comparison of CTCA with ICA and sort out clinical precision of CTCA using the ICA-based strategy as gold standard.

It is important to realise that in patients who qualify for a 'CTCA-first' strategy, the need for subsequent use of ICA and/or revascularisation mounts up to 34% and even 50%, in expert centres.[16 17] It is therefore reassuring that in our study CTCA correctly identified the majority of patients who end up with medical therapy and/or revascularisation.

Small vessel disease

Pathology reports and subsequently studies using ICA have demonstrated that CAD most frequently involves the proximal portions of the major epicardial vessels.[18–20] When the burden of atherosclerosis increases, it also starts to affect the distal segments but always to a lesser extent as compared with the proximal parts of the coronary tree.[21]

This 'proximal-to-distal' distribution of CAD was also obvious in our study: significant CAD affecting the large-vessel and small-vessel segments occurred in, respectively, 40% and 16% of the population.

In view of the higher spatial resolution, disease in small vessel segments will be better visualised using ICA.

Table 6 Patient management

Analysis	Overall	Significant CAD in large-vessel segments only	Significant disease in small-vessel segments only
Total	826	328	29
Therapy			
Conservative	377	41	9
Medical	189	47	16
PCI	180	176	4
CABG	56	56	0
Other	24	8	/

CABG, coronary artery bypass grafting; CAD, coronary artery disease; PCI, percutaneous coronary intervention.

Table 7 Results of invasive coronary angiography and subsequent therapy in patients with CACS ≥1000

Calcium score too high	No of patients
Non-significant stenosis	60 (30%)
Significant stenosis (≥50% stenosis, any vessel)	140 (70%)
Therapy	
Conservative	52 (26.0%)
Medical	38 (19.0%)
PCI	68 (34.0%)
CABG	37 (18.5%)
Other	5 (2.5%)

CABG, coronary artery bypass grafting; CACS, Coronary Artery Calcium Score; PCI, percutaneous coronary intervention.

Indeed, diagnostic performance of CTCA in our study was substantially lower when focusing on these small vessel segments and is in accordance with the results of previous reports on this subject.[15 22]

The systematic exclusion of vessel segments with a diameter below 1.5 or 2 mm, easily mounts up to at least 10% of the coronary tree.[16] This 'pruning of the framework' which is eventually used for further study involves two consequences: (1) overestimation of the 'real-world' diagnostic accuracy and (2) the possibility of overlooking clinically relevant findings as they would affect further patient management. In our study, significant disease in small vessel segments occurred in 16% of the population and was often combined with disease in large segments. The prevalence of significant CAD limited to the small vasculature was very low but not negligible and occurred in 3.5% of the patients. When translated to disease with clinical impact, this would affect less than 1% (6 out of 29 patients needed antianginal therapy and/or revascularisation) of the population. From a statistical standpoint this would be a negligible number. From an individual's standpoint who is seeking medical advice, the uncovering and appropriate treatment of small vessel disease could make a significant difference in well-being.

Patients with a high calcium score

The utilisation of a CACS threshold before deciding to administer contrast remains controversial.[23 24] We are in favour of using such a threshold, in our study a CACS ≥1000, for two reasons.

First, CTCA remains most useful for excluding the presence of CAD in patients with a low-to-intermediate pretest probability of having significant CAD, or in other words being a reliable non-invasive alternative to ICA for patients with atypical chest pain in whom the prevalence of significant CAD is low. Patients with a high CACS, typically above 400, define a category in whom the prevalence of significant CAD on ICA is high, irrespective of the patient pretest likelihood.[25] For this reason, in the multicentre SpiralComputed Tomography Angiography Using 64 Detectors (CORE64) trial, patients with a CACS above 600 were excluded from the main analysis.[16] This specific patient group demonstrated a prevalence of significant CAD of 89% on ICA.[26] In these circumstances, that is, high likelihood of significant CAD, the chances of missing out significant disease becomes as high as 37%.[26]

Second, in the presence of significant CAD or high likelihood of this condition, the point of interest becomes not the stenosis per se, but whether the stenosis is producing ischemia and revascularisation would become necessary. To resolve the issue of ischemia, it has become clear that ICA in combination with functional assessment using fractional flow reserve would be the preferred strategy, or as an alternative the addition of another noninvasive functional test.[27 28]

Limitations

To determine the clinical impact of CTCA, we relied on the therapeutic recommendation of the treating physician, which was driven by the findings on ICA. We subsequently assessed whether the CTCA report withheld the diagnosis of significant CAD or not and used this as a proximate to identify patients in whom revascularisation and/or antianginal drug therapy would be necessary. Ideally, a prespecified management plan, initially based on the findings of CTCA and subsequently compared with the recommendations after performance of ICA, would have been analysed in a prospective way.

However, it should be stressed that CTCA essentially should be used as gatekeeper and not as a substitute for ICA.[1] The knowledge that the majority of patients in whom medical treatment or revascularisation appeared to be necessary were identified on the index CT scan, is an add-on comforting idea.

The a priori exclusion of coronary segments smaller than 1.5 or 2 mm is common practice in most CTCA studies and could contribute to the perception that small vessel pathology represents an entity of minor clinical importance as compared with the larger and proximally located coronary arteries, which are almost exclusively targeted for CABG or PCI. As is obvious from this study, small vessel disease targeted for medical therapy and/or revascularisation is relatively infrequent but not absent. In addition, we should not forget that chest pain in the absence of obstructive CAD, so-called microvascular angina, frequently finds its origin in the coronary microcirculation, which actually cannot be visualised through any in vivo imaging technique in humans.[29] Microvascular angina is by no means infrequent in clinical practice and needs for its definitive diagnosis advanced functional testing such as positron emission tomography or invasively obtained coronary physiology parameters.[30]

CONCLUSIONS

From a true patient perspective, without a priori exclusion of smaller coronary artery segments, CTCA allows safe patient management. Anatomically significant disease limited to the small vasculature is relatively uncommon and rarely needs antianginal treatment or revascularisation.

Contributors YL: methodology, data curation, original draft preparation, writing, software, visualisation. LVH: data curation, reviewing and editing. PV: data curation, reviewing and editing. OB: data curation, reviewing and editing. PS: data curation, reviewing and editing. EK: data curation, reviewing and editing. CVM: Conceptualisation, methodology, original draft preparation, data curation, writing, reviewing and editing, supervision.

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