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Prognostic Implications of Nonobstructive Coronary Plaques in Patients With Non–ST-Segment Elevation Myocardial Infarction

A Multidetector Computed Tomography Study

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Objectives We sought to determine whether the amount of noncalcified plaque (NCP) in nonobstructive coronary lesions as detected by multidetector computed tomography (MDCT) was a predictor of future coronary events.

Background Patients presenting with non–ST-segment elevation myocardial infarction (NSTEMI) frequently have multiple coronary plaques, which may be detected with MDCT.

Methods We included 312 consecutive patients presenting with NSTEMI, who underwent 64-slice MDCT coronary angiography and coronary artery calcium scoring before invasive coronary angiography. All patients were treated according to current guidelines based on an invasive treatment approach. Quantitative measurements of plaque composition and volume were performed by MDCT in all nonobstructive coronary lesions. The endpoint was cardiac death, acute coronary syndrome, or symptom-driven revascularization.

Results After a median follow-up of 16 months, 23 patients had suffered a cardiac event. Age, male sex, and diabetes mellitus were all associated with an increasing amount of NCP. In a multivariate regression analysis for events, the total amount of NCP in nonobstructive lesions was independently associated with an increased hazard ratio (1.18/100-mm^3 plaque volume increase, $p = 0.01$). Contrary to this, neither Agatston score nor the amount of calcium in nonobstructive lesions was associated with an increased risk.

Conclusions Multidetector computed tomography plaque imaging identified patients at increased risk of recurrent coronary events after NSTEMI by measuring the total amount of NCP in nonobstructive lesions. The amount of calcified plaque was not associated with an increased risk. (J Am Coll Cardiol 2011;58:502–9) © 2011 by the American College of Cardiology Foundation

Acute coronary syndrome (ACS) and sudden cardiac death is frequently the first clinical manifestation of coronary artery disease (CAD). The most common cause of ACS is thrombus formation because of ruptured or eroded coronary plaques (1–3). Coronary plaque disruption is typically associated with plaques containing a large necrotic core covered by a thin fibrous cap (4). Despite optimal contemporary invasive and medical treatment, the coronary event rate in patients with ACS remains increased, compared with patients with stable symptoms (5). Growing evidence suggest that this phenomenon could be a consequence of multiple destabilized and vulnerable plaques throughout the coronary tree (6–10).

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Noninvasive imaging of the coronary arteries with multidetector computed tomography (MDCT) has emerged as an important modality in the diagnostic work-up of patients suspected of CAD. Noncontrast-enhanced coronary artery calcium scoring (CACS) has been shown to be an independent marker of future coronary events in asymptomatic individuals with coronary risk factors (11), and contrast-enhanced MDCT coronary angiography (CAG) has proven to be useful in ruling out significant obstructive atherosclerotic disease in symptomatic patients with an intermediate pre-test likelihood of CAD (12). In addition, visualization

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of coronary plaque composition has become possible with this technique, allowing a fast noninvasive evaluation of the overall plaque burden in the coronary tree with characterization of calcified and noncalcified plaque (NCP) components (13–21).

In this prospective study, we tested the hypothesis that global coronary plaque burden in nonobstructive lesions measured with MDCT predicts intermediate-term clinical outcome in patients with non–ST-segment elevation myocardial infarction (NSTEMI).

Methods

Patient selection and study design. In the period from December 2006 to August 2008, all patients referred for invasive CAG at our institution due to NSTEMI—defined as acute chest pain, elevated troponin-T, and absence of ST-segment elevation—were screened for participation in the study (n = 1,051). Exclusion criteria were elevated serum creatinine (n = 123), irregular heart rate (n = 45), hemodynamic/respiratory instability (n = 12), allergy to iodine contrast media (n = 5), and refusal to participate (n = 40). Among eligible patients (n = 826), it was not possible to obtain scanning data in 504 for logistical reasons (mainly due to scanner availability and coincidence with the invasive procedure). Thus, the final study population consisted of 322 patients. All included patients underwent MDCT before invasive CAG, and both procedures were performed within the same day. Treatment strategy was performed on the basis of clinical and invasive findings according to international guidelines blinded to MDCT findings (22).

Medical history and cardiovascular risk profile of the patients were acquired from hospital charts. The minimum follow-up time was 6 months, and follow-up data were gathered from an electronic database containing vital status and discharge letters for all admissions in Denmark (Green System, CSC Scandihealth, Aarhus, Denmark). The composite endpoint was defined as cardiovascular death, myocardial infarction (MI), unstable angina requiring hospital stay, or symptom-driven revascularization. All patients gave written informed consent, and the local ethics committee approved the study protocol.

MDCT scan protocol. All patients were pre-treated with oral beta-blockers, unless contraindicated. Image acquisition was performed with a 64-slice MDCT (Aquilion 64, Toshiba, Tokyo, Japan). First, a non–contrast-enhanced, prospectively electrocardiogram-triggered calcium score was performed at 75% of the R–R interval.

Subsequently, a coronary computed tomography (CT) angiography was performed with the following parameter settings: 64 × 0.5 mm detector collimation, 120 to 135 kV tube voltage, 380 to 450 mA tube current, 350 to 500 ms gantry rotation time (heart rate-dependent). Intravenous contrast media (Visipaque 320, GE Healthcare, Chalfont St. Giles, United Kingdom) was infused with a flow rate of 5 ml/s with a biphasic injection protocol. First, a 70 to 100 ml contrast bolus was injected (depending on expected scan time), followed by a 30 ml 70%/30% contrast/saline mix. Finally, a 30-ml saline chaser was injected. The automatic bolus triggering technique was used for initiating image acquisition. An automatic raw data motion analysis tool (PhaseXact, Toshiba) was used to determine the optimal systolic and diastolic phases for reconstruction. Additional reconstructions at end systole (30% to 40% of the R–R interval) and mid-diastole (70% to 80% of the R–R interval) were routinely reconstructed. All phases were evaluated to identify the optimal phase for evaluation of each coronary artery. Images were reconstructed with 0.5-mm slice thickness and increments of 0.3 mm. Finally, reconstructions with a 2.0-mm slice thickness and a 2.0-mm increment were performed with 5% intervals throughout the entire cardiac cycle for functional analysis.

Abbreviations and Acronyms

ACS = acute coronary syndrome
CACS = coronary artery calcium scoring
CAD = coronary artery disease
CAG = coronary angiogram/angiography
CT = computed tomography
HU = Hounsfield units
IVUS = intravascular ultrasound
LVEF = left ventricular ejection fraction
MDCT = multidetector computed tomography
MI = myocardial infarction
NCP = noncalcified plaque
NSTEMI = non–ST segment elevation myocardial infarction
ROC = receiver-operator characteristic

Data analysis. All image data were transferred to an external workstation (Vitrea 2, version 4.0, Vital Images, Inc., Plymouth, Minnesota) for further analysis blinded to clinical information and findings of the invasive CAG.

First, the noncontrast-enhanced images were evaluated with the Agatston score. In patients with a history of revascularization, coronary segments with stents were excluded.

Second, analysis of the contrast-enhanced images was performed in all coronary arteries more than 1.5 mm in diameter. The coronary arteries were evaluated for the presence of any plaque in axial and multiplanar reconstructions. In patients with a history of bypass surgery, coronary segments with a patent bypass graft distally were excluded for further analysis. Patients with severe motion artifacts in at least 1 major coronary artery were excluded for further analysis. Patients with motion artifacts in side branches were accepted, and only the coronary segment with motion artifacts was excluded. In each coronary lesion—defined as any plaque between 2 normal coronary segments—measurements of plaque morphology were performed with a dedicated software tool, $^{\text{SURE}}$Plaque (Vitrea 2, version 4.0, Vital Images, and Toshiba Medical Systems), previously validated against intravascular ultrasound (IVUS) and evaluated in different clinical settings (14,23). The vessel centerline was located with an automatic vessel-tracking algorithm based on the opacification of the lumen. The plaque analysis performed by the software is based on an automatic detection of the outer contour of the vessel with a ray search

technique on cross sections perpendicular to the vessel. In cases of inaccuracies at side branches or in heavily calcified plaques, manual corrections of the lumen border and vessel wall were performed. Coronary plaque was defined as the area between the outer contour of the vessel and the lumen border. The total plaque volume was calculated as the sum of all contiguous voxels between the outer vessel contour and the lumen border. Within this plaque, plaque content exceeding a threshold of 130 Hounsfield units (HU) was calculated as the calcium volume and plaque content below 130 HU as NCP volume. Finally, the mean attenuation of the NCP volume was determined as the average HU corresponding to the entire NCP lesion (Fig. 1). Intraobserver and interobserver variability of plaque measurements was examined in a subgroup of 50 patients. Reproducibility calculations were performed on previously selected cardiac phases.

In all coronary segments, any visible plaque on MDCT—regardless of the degree of stenosis—was evaluated. On the basis of the results from the invasive angiography upon which the clinical decision-making was based, plaques in coronary segments without any obstructive lesion (diameter stenosis >50%) were defined as nonobstructive plaque. The sum of all recorded nonobstructive volumes (mm^3)/patient was calculated. In an additional analysis, mean plaque attenuation of NCP in both nonobstructive and obstructive lesions was recorded.

Left ventricular function was measured as previously described (24).

Statistical analysis. Statistical analyses were performed with SPSS (version 16.0, SPSS, Inc., Chicago, Illinois). Receiver-operator characteristic (ROC) curves were compared with MedCalc version 11.4. Numerical values are presented as mean ± SD, and categorical values are presented as frequencies and percentages unless otherwise stated. For statistical comparisons, a 2-tailed *t* test for independent samples was used for continuous values, and the chi-square test was used for categorical variables. Numerical values that were not normally distributed were compared with the Mann-Whitney *U* test and are presented as median and interquartile range. Analysis of variance for linear trend and chi-square test for trend were used to test differences between ordered groups. Correlation between calcified plaque and NCP volumes was assessed with Spearman correlation coefficient. Intra- and inter-observer variability was assessed with Bland-Altman analysis and the intraclass correlation coefficient.

The relationships among MDCT variables, clinical variables, and clinical outcome variables were assessed with Cox proportional hazards regression. First, a univariable analysis was performed for each of the following potential MDCT predictors of clinical events: Agatston score, nonobstructive NCP volume, nonobstructive calcified plaque volume, total nonobstructive plaque volume, and number of coronary segments with any nonobstructive plaque. Second, a multivariate regression analysis for each MDCT predictor was performed to adjust for established clinical predictors (age,

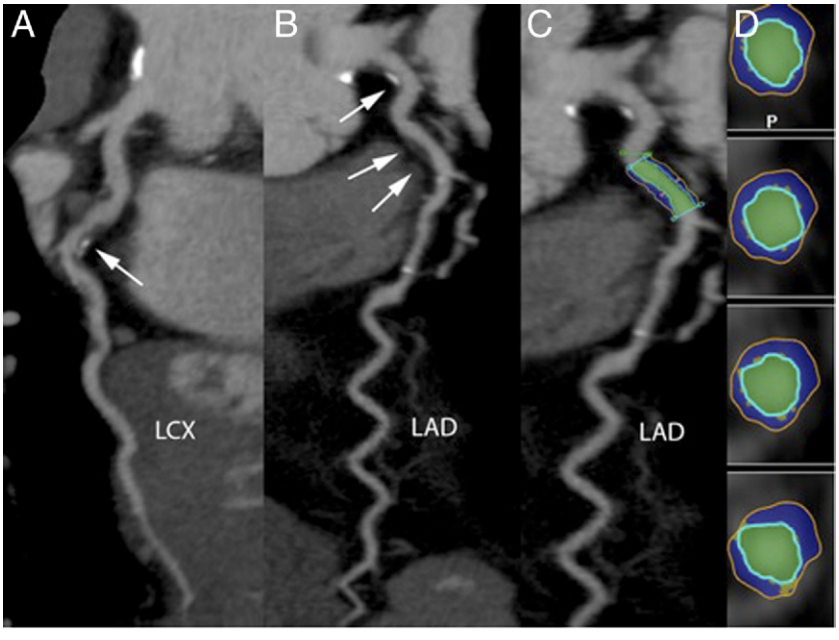

Figure 1 **Evaluation of Coronary Plaques With Computed Tomography**

Example of a 64-year-old man presenting with non–ST-segment elevation myocardial infarction. The culprit lesion is seen in the proximal part of the left circumflex artery (LCX) **(white arrow)**. This lesion has both calcified and noncalcified components **(A)**. Additional nonobstructive plaques are found in the left main **(single arrow)** and proximal left anterior descending (LAD) artery **(double arrow) (B)**. The plaque analysis tool applied to the lesion in a curved multiplanar reconstruction **(C)** and transverse sections **(D)**. The **blue color** represents noncalcified plaque and **yellow**, calcifications.

Table 1 Clinical Characteristics and In-Hospital Management

n	312
Male	230 (74%)
Age (yrs)	61 ± 12
Body mass index (kg/m^2)	27 ± 5
eGFR (ml/min)	84 ± 23
Medical history	
Diabetes	46 (15%)
Current smoker	118 (38%)
Hypercholesterolemia	171 (55%)
Hypertension	138 (44%)
Family history of CAD	132 (42%)
History of myocardial infarction or revascularization	74 (24%)
Heart rate (beats/min)	59 ± 11
LVEF by MDCT (%)	58 ± 13
Findings on invasive coronary angiography	
1-vessel disease	112 (36%)
2-vessel disease	81 (26%)
3-vessel disease	49 (16%)
Left main disease	24 (8%)
Treatment decision	
PCI	181 (58%)
CABG	53 (17%)
Medication at discharge	
Aspirin	287 (96%)
Clopidogrel	246 (79%)
Beta-blocker	268 (86%)
Statin	231 (93%)

CABG = coronary artery bypass grafting; CAD = coronary artery disease; eGFR = estimated glomerular filtration rate; LVEF = left ventricular ejection fraction; MDCT = multidetector computed tomography; PCI = percutaneous coronary intervention.

presence of multivessel disease, prior MI, and left ventricular ejection fraction). The proportional hazard assumption was checked through calculation of correlation between Schoenfeld residuals and ranked survival times. The incremental prognostic value of MDCT predictors to clinical variables was assessed by calculating the area under curve for ROC curves of nonobstructive plaque volumes + clinical variables and clinical variables alone.

Results

Coronary CT angiography was performed in 322 patients. Patients not included for logistical reasons tended to be older (66 vs. 61 years, $p < 0.001$) and to have a poorer renal function (estimated glomerular filtration rate 80 vs. 84 ml/min, $p > 0.001$) and a higher prevalence of 3-vessel disease (21% vs. 16%, $p = 0.04$) but did not differ with regard to risk factors or treatment strategy. In 10 of the included patients (3%), at least 1 major coronary artery segment was not evaluable due to motion artifacts, and these patients were excluded from further analysis. These patients did not differ in baseline characteristics from the final study population, except for a significantly higher heart rate (69 ± 15 beats/min vs. 59 ± 11 beats/min) during MDCT. Baseline characteristics of the remaining 312 patients are delineated in Table 1. After exclusion of 42 coronary segments with stents and 162 segments with chronic occlusion or small vessel size, a total of 1,454 coronary artery segments with plaques were identified and analyzed.

The median Agatston score was 349 (42 to 1,059) and was correlated to the total NCP volume ($r = 0.69$, $p < 0.001$). Forty patients (13%) had an Agatston score of 0, and 14 of these had obstructive lesions (35% of 0-calcium patients). In the entire study group, the mean number of diseased segments/patient was 5.2 ± 3.5.

The invasive CAGs identified 313 obstructive coronary lesions that subsequently were the target of revascularization. The MDCT identified 1,141 nonobstructive lesions that were left untreated. The total nonobstructive NCP volume stratified by tertiles is presented in Table 2 with corresponding baseline risk factors. Advanced age, male sex, and diabetes were associated with higher nonobstructive NCP volumes.

Mean attenuation of NCP between obstructive and nonobstructive lesions was not significantly different (70 ± 24 vs. 71 ± 26, $p = 0.16$).

Intraobserver limits of agreement were ±68 mm^3 for calcified and ±125 mm^3 for NCP volumes, whereas interobserver limits of agreement were ±64 mm^3 and ±168 mm^3, respectively. The corresponding intraclass correlation coefficients were 0.89, 0.91, 0.92, and 0.81, respectively.

After a median of 16 months of follow-up (range 6 to 30 months), 23 events had occurred, including 6 cardiovascular deaths, 8 nonfatal MIs, 5 admissions with unstable angina and repeated CAG, and 4 clinically driven revascularizations. Four patients were censored because of noncardiovas-

Table 2 Baseline Risk Factors Stratified by Tertiles of Nonobstructive NCP Volume

	Nonobstructive NCP Volume in Tertiles			
Risk Factors	0–118 mm^3 (n = 104)	118–346 mm^3 (n = 104)	348–1,741 mm^3 (n = 104)	p Value
Age (yrs)	56 ± 12	61 ± 12	66 ± 10	<0.001
Male	66 (64%)	78 (75%)	86 (83%)	0.007
Diabetes	10 (10%)	7 (7%)	23 (22%)	0.01
Current smoker	38 (37%)	47 (45%)	33 (32%)	0.4
Hypertension	36 (35%)	55 (53%)	47 (45%)	0.08
Hypercholesterolemia	58 (56%)	68 (65%)	45 (43%)	0.08
Family history of CAD	47 (45%)	41 (39%)	44 (42%)	0.13

CAD = coronary artery disease; NCP = noncalcified plaque.

Table 3 Univariate and Adjusted MDCT Plaque Predictors of Coronary Events

	Univariate HR (95% CI)	p Value	Adjusted HR (95% CI)	p Value
Agatston score	1.02 (0.98–1.09)	0.34	1.01 (0.96–1.06)	0.59
Nonobstructive NCP volume (per 100 mm^3 increase)	1.17 (1.06–1.30)	0.002	1.18 (1.06–1.31)	0.002
Total nonobstructive plaque volume (per 100 mm^3 increase)	1.06 (1.02–1.10)	0.005	1.06 (1.01–1.11)	0.01
Nonobstructive calcified plaque volume (per 100 mm^3 increase)	1.07 (1.01–1.14)	0.02	1.07 (0.99–1.16)	0.06
Number of segments with any nonobstructive plaque	1.13 (1.01–1.26)	0.04	1.12 (0.94–1.26)	0.24

Adjusted for age, presence of multivessel disease, prior myocardial infarction, and left ventricular ejection fraction.
CI = confidence interval; HR = hazard ratio; MDCT = multidetector computed tomography; NCP = noncalcified plaque.

cular deaths: 1 lung embolus, 1 cancer, and 2 severe infections.

In the univariate Cox regression analysis, significant MDCT plaque predictors of clinical events were nonobstructive NCP volume, total nonobstructive plaque volume, nonobstructive calcified plaque volume, and number of segments with any nonobstructive plaque. In 5 separate multivariate models for each MDCT plaque predictor, only the nonobstructive NCP volume and total nonobstructive plaque volume were significant predictors of cardiac events after adjusting for the following clinical variables: age, presence of multivessel disease, history of MI, and left ventricular ejection fraction (Table 3). Adjusted survival curves based on stratification of NCP-volumes in tertiles are shown in Figure 2. In an additional analysis for hard events only (death or MI), the univariate hazard ratio for nonobstructive NCP was 1.14 ($p = 0.04$). There was no difference in mean plaque attenuation of nonobstructive NCP between patients with and those without events (71 ± 25 vs. 72 ± 23, $p = 0.24$).

The area under the curve of ROC curves for nonobstructive NCP + clinical variables was 0.70 ($p = 0.001$), 0.68 for total nonobstructive plaque volume + clinical variables, 0.66 ($p = 0.02$) for nonobstructive calcified plaque + clinical variables, and 0.61 ($p = 0.04$) for clinical variables alone (Fig. 3). Only area under the curve for NCP + clinical variables was significantly higher than clinical variables alone ($p = 0.04$).

Discussion

To our knowledge, this study is the first to demonstrate that evaluation of nonobstructive coronary lesions with MDCT identifies patients at an increased risk after an acute coronary event. Indeed, the nonobstructive NCP volume was a better predictor of future cardiac events than clinical variables and LVEF. Furthermore, we demonstrated that NCP was a stronger predictor than both the calcified and total plaque volume.

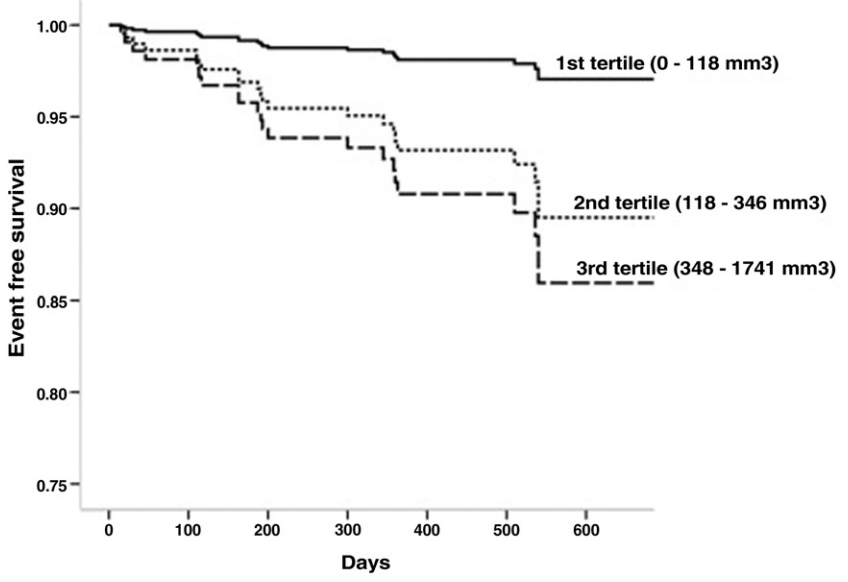

Figure 2 Adjusted Survival Curves

Survival curves for the study population stratified in tertiles of the nonobstructive noncalcified plaque volume adjusted for age, presence of multivessel disease, prior myocardial infarction, and left ventricular ejection fraction ($p = 0.056$ for first vs. second tertile, and $p = 0.034$ for first vs. third tertile).

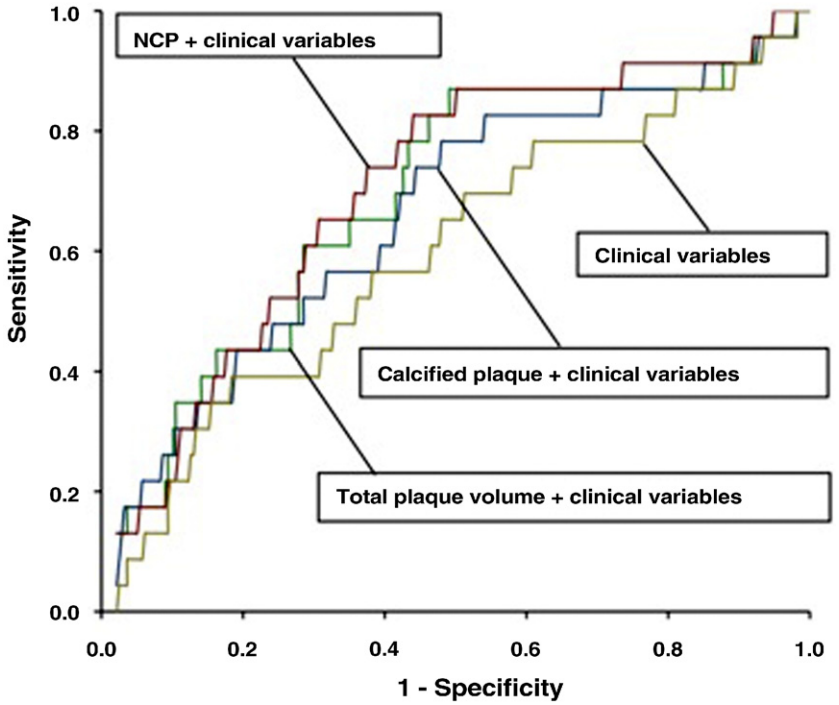

Figure 3 **Receiver-Operator Characteristic Curves**

Receiver-operator characteristic curves created as a combination of multidetector computed tomography plaque measurements and clinical variables demonstrating the ability to predict coronary events. Area under the curve for noncalcified plaque (NCP) + clinical variables, 0.70 ($p < 0.001$); total plaque volume, 0.68 ($p < 0.001$); calcified plaque + clinical variables, 0.66 ($p = 0.02$); and clinical variables alone, 0.60 ($p = 0.04$). Only area under the curve for NCP + clinical variables was significantly higher than clinical variables alone ($p = 0.04$).

Current guidelines for the management of patients with NSTEMI include pharmacological stabilization, CAG, and revascularization of obstructed vessels (22). However, patients presenting with ACS have an increased risk of recurrent coronary events even after optimal contemporary invasive and medical treatment, and the presence of multiple vulnerable plaques might play an important role.

The importance of identifying nonculprit vulnerable plaques has previously been demonstrated in patients with MI. Both Goldstein et al. (9) and Rioufol et al. (25) showed that patients with multiple complex lesions had worse clinical outcomes than patients with a single lesion. Mauriello et al. (8) found that patients dying from MI had an average of 6.8 ± 0.5 vulnerable segments compared with 0.8 ± 0.3 vulnerable segments in patients with stable angina. However, the clinical implications of detecting additional vulnerable plaques remain controversial, and imaging criteria to identify patients at risk are still being evaluated.

Plaques prone to rupture or erosion have been shown to contain a large necrotic core covered by a thin fibrous cap, whereas only a minority of the predominantly calcified plaques are involved in acute thrombus formation (1–4).

Comparisons of MDCT with IVUS for the characterization of plaque morphology have shown an excellent agreement for the identification of noncalcified and calcified plaques (15,19,26–28). However, the spatial resolution with current CT scanners is still inadequate to differentiate between subtypes of NCPs. Preliminary studies comparing fibrous, fibro-fatty, and lipid-rich plaque components on the basis of CT attenuation values have shown substantial overlap (15,19,26,28–30). Nevertheless, distinct differences between culprit lesions in ACS and lesions in stable angina have been reported, with MDCT showing a significantly higher frequency of noncalcified and mixed plaque types, positive remodeling, and lower signal intensity in plaques associated with ACS (13,14,18,20). Although current MDCT scanners might not be able to detect the individual vulnerable plaque, we hypothesized that the total NCP volume could serve as a marker of the overall vulnerable plaque burden.

Coronary artery calcium scoring with MDCT has been introduced as a noninvasive method to detect coronary artery plaques in asymptomatic persons with risk factors (11). However, acute coronary events are usually triggered by plaque disruption in NCPs (1,2,4), and the prognostic value of CACS in patients with known CAD has not been established. The correlation between calcified plaque and NCP is assumed to be linear, thus making CACS a surrogate marker of the overall plaque burden. This assump-

tion might be reasonable in asymptomatic individuals with a low prevalence of coronary atherosclerosis but has not been assessed in patients with known CAD.

In this study, 2 important findings with regard to CACS in patients with NSTEMI should be noted. Forty patients (13%) had an Agatston score of 0, of which 14 (35%) had obstructive lesions. A calcium score of 0 thus seems to be a relatively common finding in patients with NSTEMI. In the remaining 26 patients (65% of 0-calcium score patients), no obstructive lesions were found representing a range of conditions that might mimic NSTEMI (i.e., pericarditis or myocarditis, coronary spasms, tachyarrhythmias, Takotsubo syndrome). The second key finding with regard to CACS was that the relationship between Agatston score and total NCP volume was only moderate. These findings suggest that, in patients with known CAD, further risk stratification relies on measurements of the NCP burden and not on detection of calcifications in the coronary arteries.

The prognostic value of detecting the burden of CAD by MDCT in predicting all-cause mortality in patients with stable symptoms was recently demonstrated by Ostrom et al. (31). In another MDCT study, Motoyama et al. (17) found a strong association between plaques with low attenuation and positive remodeling and the development of ACS in 1,059 patients with stable symptoms. Of 45 patients classified to have vulnerable plaques, 10 (22%) developed ACS within a mean follow-up of 27 months. Their study has demonstrated that detection of vulnerable plaque with MDCT is feasible. However, in our study we found no difference in plaque attenuation of NCP between nonobstructive and obstructive lesions. This finding has previously been shown in a study using both MDCT and IVUS in patients with ACS (16). Similarly, we found no difference in plaque attenuation between patients with and those without events. These observations could be explained by the fact that patients with ACS are more likely to have diffuse involvement of several coronary arteries, compared with patients with stable CAD, and that, therefore, a small difference in plaque attenuation remains undetectable.

In conclusion, MDCT plaque imaging of patients with ACS could potentially lead to identification of patients who might benefit from new pharmacological or invasive preventive strategies.

Study limitations. First, follow-up time was limited, resulting in a relatively small number of clinical events, which weakened the statistical strength of the multivariate analysis. However, this study should be considered a proof-of-concept study, and the a priori hypothesized predictor was highly significant, allowing a less conservative strategy for inclusion of established clinical covariates in the multivariate model (32). Although nonobstructive NCP was a significant predictor in both univariate and multivariate analysis, a number of other possible clinical variables were not explored. Follow-up data were obtained from electronic discharge letters, and evaluation of new culprit lesions in the event group did not permit a lesion-specific comparison with our MDCT data. Larger studies with longer follow-up and comparison with event-driven CAGs are required to further establish MDCT criteria of plaque vulnerability. Second, a substantial number of patients were not included for logistical reasons—mainly due to scanner availability and coincidence with invasive CAG. Patients not included in the study for logistical reasons were similar to included patients with regard to all clinical and angiographic characteristics except for age, renal function, and a slightly higher prevalence of 3-vessel disease. Although the differences were minor, this could potentially limit the generalization of our results. Third, we acknowledge that the MDCT technique needs further technical improvement. Reproducibility of plaque volume measurements remains suboptimal, and with the observed limits of agreement, the risk of being misclassified to the wrong group of tertiles should be considered. In addition, reliable criteria for defining various plaque components on the basis of attenuation need to be established. Multi-energy is a promising new technique that could improve this discrimination of plaque components. Finally, radiation and total contrast load are issues of concern when adding a coronary CT angiography to the diagnostic work-up in patients with ACS. However, new scanner types with radiation doses as low as 1 mSV with prospective electrocardiogram-triggering have recently been introduced, allowing a more liberal use of the technique (33). The contrast required to perform a coronary CT angiography during the index admission could increase the risk of developing contrast-induced nephropathy. Nevertheless, during follow-up, none of the patients included in the study were admitted for renal insufficiency. Future studies should evaluate the risk/benefit ratio of sequential cardiac CT and invasive catheterization. In this type of patient, overall contrast use could remain unchanged or even decline, because presence, extent, and characteristics of coronary pathology identified by cardiac CT could reduce the amount of subsequent contrast injection needed during invasive catheterization.

Conclusions

Coronary CT angiography identified patients at increased risk of recurrent coronary events after NSTEMI by measuring the total amount of NCP in nonobstructive lesions and was a better predictor of events than clinical variables. The amount of calcified plaque was not associated with an increased risk. This method could be useful for identifying patients at risk after an episode of ACS and guide new preventive strategies.

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