Journal of Cardiovascular Computed Tomography 8 (2014) 368–374

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofCardiovascularCT.com

Original Research Article

Comparison of quantitative atherosclerotic plaque burden from coronary CT angiography in patients with first acute coronary syndrome and stable coronary artery disease

Damini Dey PhD[a,*], *Stephan Achenbach MD, FACC*[b], *Annika Schuhbaeck MD*[b], *Tobias Pflederer MD*[b], *Ryo Nakazato MD, PhD*[c], *Piotr J. Slomka PhD, FACC*[d], *Daniel S. Berman MD, FACC*[c], *Mohamed Marwan MD*[b]

[a] *Department of Biomedical Sciences, Biomedical Imaging Research Institute, Cedars-Sinai Medical Center, Taper Building, Room A238, 8700 Beverly Boulevard, Los Angeles, CA 90048, USA*
[b] *Department of Internal Medicine 2, University of Erlangen, Erlangen, Germany*
[c] *Department of Imaging and Cedars-Sinai Heart Institute, Cedars-Sinai Medical Center, Los Angeles, CA, USA*
[d] *Department of Medicine, Cedars-Sinai Medical Center, Los Angeles, CA, USA*

ARTICLE INFO

Article history:
Received 16 August 2013
Received in revised form
15 February 2014
Accepted 15 July 2014

Keywords:
Coronary plaque
Plaque volume
Plaque burden
Coronary CT angiography
Plaque quantification
Quantitative coronary tree analysis
Acute coronary syndrome

ABSTRACT

Background: Coronary CTA allows characterization of non-calcified and calcified plaque and identification of high-risk plaque features.
Objective: We aimed to quantitatively characterize and compare coronary plaque burden from CTA in patients with a first acute coronary syndrome (ACS) and controls with stable coronary artery disease.
Materials and methods: We retrospectively analyzed consecutive patients with non-ST-segment elevation myocardial infarction (NSTEMI) or unstable angina with a first ACS, who underwent CTA as part of their initial workup before invasive coronary angiography and age- and gender-matched controls with stable chest pain; controls also underwent CTA with subsequent invasive angiography (total n = 28). Culprit arteries were identified in ACS patients. Coronary arteries were analyzed by automated software to quantify calcified plaque (CP), noncalcified plaque (NCP), and low-density NCP (LD-NCP, attenuation <30 Hounsfield units) volumes, and corresponding burden (plaque volume × 100%/vessel volume), stenosis, remodeling index, contrast density difference (maximum percent difference in attenuation/cross-sectional area from proximal cross-section), and plaque length.
Results: ACS patients had fewer lesions (median, 1), with higher total NCP and LD-NCP burdens (NCP: 57.4% vs 41.5%; LD-NCP: 12.5% vs 8%; $P \leq .04$), higher maximal stenoses (85.6% vs 53.0%; $P = .003$) and contrast density differences (46.1 vs 16.3%; $P < .006$). Per-patient

Conflict of interest: This study was supported by the German Government, Bundesministerium für Bildung und Forschung (01EX1012B, "Spitzencluster Medical Valley") and by a grant from the American Heart Association (09GRNT2330000). Damini Dey, Daniel Berman, and Piotr Slomka may receive a minor part of the royalties received by Cedars-Sinai Medical Center (Los Angeles, CA) for the licensing of the software used in the quantitative assessment of coronary plaque. The other authors declare that they have no conflicts of interest.

* Corresponding author.
E-mail address: Damini.Dey@cshs.org (D. Dey).

1934-5925/$ – see front matter
http://dx.doi.org/10.1016/j.jcct.2014.07.007

CP burden was not different between ACS and controls. NCP and LD-NCP plaque burden was higher in culprit vs nonculprit arteries (NCP: 57.8% vs 9.5%; LD-NCP: 8.4% vs 0.6%; $P \leq .0003$); CP was not significantly different. Culprit arteries had increased plaque lengths, remodeling indices, stenoses, and contrast density differences (46.1% vs 10.9%; $P \leq .001$).

Conclusion: Noninvasive quantitative coronary artery analysis identified several differences for ACS, both on per-patient and per-vessel basis, including increased NCP, LD-NCP burden, and contrast density difference.

1. Introduction

Noninvasive measurement of coronary atherosclerotic plaque morphology and burden may contribute to cardiovascular risk stratification and monitoring the course of coronary artery disease. Coronary CT angiography (CTA) using multidetector CT is an effective imaging technique for noninvasive assessment of the coronary arteries.[1–3] Coronary CTA permits characterization of noncalcified plaque (NCP) and calcified plaque (CP) [4–8] and allows identification of high-risk plaque features. Several investigators have compared plaque characteristics and morphology in patients with suspected acute coronary syndrome (ACS) and stable coronary disease and shown that the CT characteristics of plaques associated with ACS include positive arterial remodeling, low plaque density, the "napkin-ring" sign, and NCP composition.[9–11] In this study, we aimed to quantitatively compare per-patient plaque measures in ACS patients vs the same measures in patients with stable disease. We also compared, on a per-vessel basis, quantitative plaque characteristics of culprit and nonculprit coronary arteries in consecutive patients presenting with a first ACS. For this analysis, we applied automated software for characterization of NCPs and CPs,[12,13] which allows rapid measurement of the plaque features from coronary CTA.

2. Materials and methods

2.1. Patients

Our study included consecutive patients presenting with a first non-ST-segment elevation ACS who underwent contrast-enhanced coronary CTA as part of their initial workup which was followed by catheterization and age- and gender-matched controls with stable coronary artery disease who also underwent coronary CTA followed by catheterization. Non-ST segment elevation ACS was defined as non-ST-segment elevation myocardial infarction (NSTEMI) or unstable angina according to American Heart Association or American College of Cardiology guidelines.[14] NSTEMI required the occurrence of elevated serial levels of cardiac troponin I (>0.5 ng/mL), collected on presentation or 6 hours after admission till their peak, with a temporal pattern consistent with acute myocardial infarction, as described previously.[15] Unstable angina was defined as new onset of severe, progressive, or resting angina suggestive of ACS and invasive coronary angiography demonstrating a 50% or greater stenosis of a major epicardial coronary artery or side branches.[15]

We retrospectively analyzed 14 consecutive NSTEMI patients and 14 matched controls. For the ACS cases, the culprit coronary artery was identified by an experienced independent interventional cardiologist blinded to CT findings, by a combination of electrocardiography findings, wall motion abnormalities in echocardiography, and angiographic lesion morphology. Controls were matched to the ACS cases by age decile and gender from consecutive patients with stable coronary artery disease, who underwent coronary CTA followed by invasive coronary angiography within a period of 14 days at the University of Erlangen. Stable coronary artery disease was defined by the presence of stable exercise-induced symptoms and no suspicion for ACS at the time of CT examination. Exclusion criteria for the study were previous myocardial infarction, coronary bypass surgery or stent placement, hemodynamic or clinical instability, atrial fibrillation, contraindications to iodinated contrast agents, and impaired renal function (creatinine level >1.4 mg/dL). The institutional review board approved the study and all patients provided a written informed consent.

2.2. CT imaging protocol

All patients were imaged with a first-generation dual-source CT scanner (SOMATOM Definition; Siemens Healthcare, Forchheim, Germany). The patient's electrocardiogram was continuously monitored throughout the procedure. In preparation for the imaging, patients with stable coronary artery disease with a heart rate >60 beats/min received oral β-blockers (atenolol 50 or 100 mg depending on body weight) at least 30 minutes before the CT examination. If heart rate remained >60 beats/min at the time of the scan in these patients, up to 4 doses of 5-mg metoprolol were given intravenously. In patients with non-ST-segment elevation ACS and a heart rate >60 beats/min before CT examination, 5 to 20 mg of metoprolol was given intravenously. A timing bolus protocol was used, with image acquisition being initiated at 2 seconds after the determined contrast transit time with 60 to 90 mL of contrast agent (350-mg iodine per mL [iomeprol]) being injected at a flow rate of 6 mL/s for coronary CTA. The section collimation was 0.6 mm with z-flying focal spot, gantry rotation time of 330 ms, reference tube current of 400 mAs per rotation, and a tube voltage of 120 kVp. All scans were performed using electrocardiography gated tube current modulation. Maximal tube current was limited to an interval of 30% to 80% of the cardiac cycle for patients with heart rates >60 beats/min and 60% to 80% for patients with heart rates ≤60 beats/min. Transverse images were reconstructed using filtered back projection with 0.75-mm slice thickness, 0.4 mm