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TABLE 1 Correlations Between MIC and Echocardiographic Variables

	ρ	95% CI	p Value
Conventional echocardiographic parameters			
EF	0.24	−0.32 to 0.66	0.40
E/A	0.52	−0.070 to 0.82	0.071
Deceleration time	−0.058	−0.59 to 0.51	0.85
e′	0.52	−0.039 to 0.82	0.059
E/e′	−0.43	−0.80 to 0.21	0.17
Echocardiographic speckle-tracking analysis			
Radial strain, %	−0.55	−0.82 to −0.026	0.036
Radial displacement, mm	−0.72	−0.90 to −0.31	0.0025
Radial velocity, cm/s	−0.82	−0.93 to −0.51	0.0002
Circumferential strain, %	0.75	0.36 to 0.91	0.0014
Circumferential strain rate, 1/s	0.44	−0.11 to 0.77	0.10
Longitudinal strain, %	0.30	−0.26 to 0.70	0.28
Longitudinal strain rate, 1/s	0.12	−0.42 to 0.59	0.67

EF = ejection fraction; MIC = myocardial iron concentration.

and adverse cardiac outcomes in patients with SCD as well as potential benefits from iron chelation.

Kana Fujikura, MD, PhD*
Anjani D. Golive, MD
Tomo Ando, MD
Francisco M. Corado, MD
Sanyog G. Shitole, MBBS, MPH
Jorge R. Kizer, MD, MSc
Aman M. Shah, MD
Martin R. Prince, MD, PhD
Daniel M. Spevack, MD, MPH
Mario J. Garcia, MD

*Cardiology Division, Department of Medicine
Montefiore Medical Center/Albert Einstein
College of Medicine
111 East 210th Street
Bronx, New York 10467
E-mail: kfujikura@bwh.harvard.edu

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Automated Quantification of Coronary Plaque Volume From CT Angiography Improves CV Risk Prediction at Long-Term Follow-Up

Accurate detection and quantification of localized but also diffuse coronary artery plaques from coronary computed tomography angiography and further differentiation of plaque tissue based on attenuation values may allow for outcome prediction of patients (1–3). The purpose of this analysis was to assess the predictive value of quantified coronary total plaque volume (TPV), low-attenuation plaque volume (LAPV), and positive remodeling (PR) using an automated software approach in a large cohort of consecutive patients with a 5-year follow-up.

The patient population, the coronary computed tomography angiography procedure, and the calculation of the Agatston score have been described in detail elsewhere (4). An automated and validated software was used to perform plaque volume quantification (QAngio CT Research Edition V2.1.16.1, Medis Medical Image Systems BV, Leiden, the Netherlands) in all 4 major coronary vessels with a luminal diameter >1.5 mm (1,2). All detected plaques were summed up for every patient to obtain TPV per patient. To obtain LAPV an algorithm that accounts for different enhancement patterns in lesions and distal parts of vessels was applied (2). PR was calculated by the software and refers to outer vessel wall diameter increase inside a plaque when compared with the proximal outer vessel wall reference diameter.

All-cause mortality and myocardial infarction (MI) served as primary endpoint. Cardiac death and acute coronary syndrome were defined as secondary cardiac endpoint. The Youden index derived from receiver operating characteristic curve analysis was used to determine optimal thresholds for risk stratification of patients into different risk groups.

Analysis is based on 1,577 patients with a median follow-up of 5.5 years (interquartile range: 5.0 to 6.2 years). The primary endpoint of all-cause mortality and MI occurred in 61 patients (48 patients died, 13 suffered from MI). The secondary cardiac endpoint occurred in 30 patients (12 patients died from cardiovascular causes and 18 experienced acute coronary syndrome). The automated plaque analysis identified 2.2 ± 3.3 plaques per patient, a mean TPV of 88 ± 181 mm^3, and a mean LAPV of 1.6 ± 4.2 mm^3. Patients suffering from the primary endpoint had significantly more plaques (3.9 ± 3.7 vs. 2.2 ± 3.3;

TABLE 1 Predictive Value of Computed Tomography Findings

	All-Cause Mortality and Myocardial Infarction			Cardiac Death and Acute Coronary Syndrome		
	Hazard Ratio	p Value	C-Index	Hazard Ratio	p Value	C-Index
Morise score	1.3 (1.2–1.4)	<0.001	0.66	1.2 (1.1–1.4)	<0.001	0.67
Any plaque	3.7 (1.6–8.7)	<0.01	0.60	12.0 (1.6–88.1)	0.01	0.63
Positive remodeling	2.6 (1.6–4.3)	<0.001	0.61	5.0 (2.4–10.2)	<0.001	0.72
Obstructive CAD	2.4 (1.4–3.9)	<0.001	0.61	3.4 (1.7–7.6)	<0.001	0.66
Quantified plaque volume			0.69			0.73
No plaque volume		Reference			Reference	
Low plaque volume	3.2 (1.5–6.6)	<0.01		12.3 (2.8–53.9)	<0.001	
High plaque volume S	6.4 (3.2–12.8)	<0.001		16.5 (3.7–72.7)	<0.001	
Low-attenuation plaque Volume			0.68			0.74
No LAPV		Reference			Reference	
Low LAPV	3.0 (1.5–6.0)	<0.01		8.1 (2.3–28.3)	<0.01	
High LAPV S	6.6 (3.4–12.9)	<0.001		14.8 (4.2–52.2)	<0.001	
Calcium scoring			0.68			0.67
0		Reference			Reference	
0–200	2.4 (1.1–5.4)	0.03		3.4 (0.9–12.0)	0.06	
>200	6.1 (2.8–13.3)	<0.001		8.2 (2.4–28.3)	<0.001	

CAD = coronary artery disease; LAPV = low-attenuation plaque volume.

$p < 0.001$), higher TPV (222 ± 357 mm^3 vs. 83 ± 169 mm^3; $p < 0.001$), higher LAPV (4.4 ± 8.6 mm^3 vs. 1.5 ± 3.9 mm^3; $p < 0.001$), higher presence of PR (41.0% vs. 20.9%; $p < 0.001$), and higher Agatston score (546 ± 985 vs.178 ± 419; $p < 0.001$).

In total, 764 (48.4%) patients had no plaques and thus no TPV and 816 patients (51.7%) had no LAPV at all ($p = 0.07$). To further stratify patients with TPV or LAPV >0 into patients at higher and lower risk for an unfavorable outcome, an ideal cutoff was calculated based on receiver operating characteristic curve statistics. This cutoff was 110.5 mm^3 for TPV and 2.67 mm^3 for LAPV. These cutoff values classified 349 (22.1%) and 261 (16.6%) patients as high risk according to TPV and LAPV, respectively ($p < 0.01$). The ideal cutoff for PR revealed by receiver operating characteristic curve analysis for future adverse events was 1.18. Table 1 illustrates the predictive value of all measured computed tomography findings. In multivariate analysis (including the Morise score as clinical risk score and obstructive coronary artery disease using a 50% threshold of luminal narrowing) the predictive value of TPV and LAPV was maintained ($p < 0.01$ for the primary and secondary endpoint).

Our analysis demonstrates that quantified coronary TPV and LAPV provide relevant prognostic information for a hard endpoint consisting of all-cause mortality and MI and a pure cardiac endpoint including cardiac death and acute coronary syndrome. Of note, the optimal cutoff for PR predicting future adverse events discovered in our analysis was higher than reported by other research groups (5).

Simon Deseive, MD*
Ramona Straub, MD
Maximilian Kupke, MD
Jonathan Nadjiri, MD
Alexander Broersen, PhD
Pieter H. Kitslaar, MSc
Steffen Massberg, MD
Martin Hadamitzky, MD
Jörg Hausleiter, MD

*Klinikum der Universität München
Medizinische Klinik und Poliklinik I
Marchioninistraße 15
81377 München
Germany
E-mail: simon.deseive@med.uni-muenchen.de

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Reduction of SPECT MPI Radiation Dose Using Contemporary Protocols and Technology

The nuclear cardiology field embarked several years ago on an aggressive effort to reduce radiation exposure for single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) (1). Several reports suggest substantial lag in the adoption of radiation-sparing approaches (2,3). However, some laboratories have made considerable progress and the impact of these efforts is not well recognized.

Data from SPECT MPI studies performed at the 4 Saint Luke's Mid America Heart Institute nuclear cardiology laboratories from January 2009 to September 2016 (n = 18,162) were reviewed. Effective dose (*E*) was calculated from the recorded actual administered dose of Tl-201, Tc-99m sestamibi, and Tc-99m tetrofosmin, using standard conversion factors (4). The department quality control committee reviewed images regularly.

In 2009, all studies were on large field of view (FOV) Anger cameras. By early 2011, Tl-201 protocols were completely eliminated. Two cadmium-zinc-telluride cameras (Spectrum Dynamics Medical, Inc., Sarasota, Florida) and 2 small FOV Anger cameras equipped with advanced post-processing software (Cardio MD, ASTONISH, Philips Medical, Bothell, Washington) replaced older generation large FOV cameras between Spring 2010 and Fall 2012. Protocols designed to minimize radiotracer (especially low-dose stress-first/stress-only protocols) were used over that time, and low-dose stress-first became a default protocol for most patients except those with prior infarction or known cardiomyopathy. Also, large FOV cameras (less appropriate for low-dose protocols) became used almost exclusively for morbidly obese patients.

After the elimination of Tl-201 and before the widespread usage of new camera technologies, mean effective dose *E* decreased from 17.9 in 2009 to a mean of 12.1 mSv. Since Fall 2012, the mean *E* of the 4,035 studies conducted on small FOV cameras with advanced post-processing software was 5.6 mSv (mean body mass index [BMI], 29.5 kg/m^2), and in the 5,592 studies performed on cadmium-zinc-telluride cameras, mean *E* was 2.8 mSv (mean BMI, 29.3 kg/m^2). For the 1,609 patients imaged on large FOV camera since 2014, mean BMI was much larger (45.8 kg/m^2), as was mean *E* (14.5 mSv). Since Fall 2012, more than 69% of MPI studies were performed using low-dose, stress-only imaging.

Overall *E* decreased dramatically over the course of the study from a mean of 17.9 mSv in 2009 to 7.2 mSv in 2016; median *E* decreased from 10.3 mSv in 2009 to 2.5 mSv in 2016, representing 60% and 76% reductions, respectively (**Figure 1**). During years 2014 to 2016, the mean dose of radiotracer rose slightly. Mean BMI also rose during this time, from 31.9 to 33.1 kg/m^2. This study demonstrates the compelling impact of a comprehensive radiation-reduction strategy in a large nuclear cardiology laboratory network. The study includes consecutive patients tested from 2009 to 2016 (over 18,000 SPECT MPI tests) and spans an era of significant advances in nuclear cardiology and changes in practice patterns.

The cumulative result has been a striking reduction in radiation dose to the patient. Mean *E* has decreased about 60%, whereas the median dose has decreased by 76%, and is now <3 mSv. Most patients the last 5 years received <3 mSv, one-third of median target dose set by the American Society of Nuclear Cardiology (1). In contrast, most patients (58%) in our laboratories in 2009 received >9 mSv. These results were achieved despite a high prevalence of obesity.

Our results show much greater reduction in radiation than the overall data from the Intersocietal Accreditation Commission and from surveys conducted by the INCAPS investigators (2,3). In the Intersocietal Accreditation Commission study of U.S. laboratories, the mean effective dose was 14.9 mSv, whereas in the INCAPS study of 308 nuclear laboratories in 65 countries, the median effective dose was 10.0 mSv (2,3).

Interventions that drove the reduction in radiation dosage include elimination of Tl-201 and dual isotope imaging protocols; and implementation of lower-dose protocols, especially low-dose, stress-only imaging, facilitated by newer cadmium-zinc-telluride camera systems and the use of small FOV Anger cameras with advanced reconstruction software.

The data presented here demonstrate that adoption of widely available hardware and software options, and implementation of stress-first/stress-only protocols are practical in real-world daily practice and can result in very low radiation exposures for SPECT MPI.