# Semiautomated Global Quantification of Left Ventricular Myocardial Perfusion at Stress Dynamic CT: Diagnostic Accuracy for Detection of Territorial Myocardial Perfusion Deficits Compared to Visual Assessment

Julian L. Wichmann, MD, Felix G. Meinel, MD, U. Joseph Schoepf, MD, Akos Varga-Szemes, MD, PhD, Giuseppe Muscogiuri, MD, Paola M. Cannaò, MD, Andrew D. McQuiston, BS, Yeon Hyeon Choe, MD, PhD, Yining Wang, MD, Carlo N. De Cecco, MD, PhD

**Rationale and Objectives:** To evaluate the diagnostic accuracy of semiautomated global quantification of left ventricular myocardial perfusion derived from stress dynamic computed tomography myocardial perfusion imaging (CTMPI) for detection of territorial perfusion deficits (PD).

**Materials and Methods:** Dynamic CTMPI datasets of 71 patients were analyzed using semiautomated volume-based software to calculate global myocardial blood flow (MBF), myocardial blood volume, and volume transfer constant. Optimal cutoff values to assess the diagnostic accuracy of these parameters for detection of one- to three-vessel territories with PD in comparison to visual analysis were calculated.

**Results:** Nonsignificant differences ($P = 0.694$) were found for average global MBF in patients without PD and single-territorial PD. Significant differences were found for mean global MBF in patients with PD in two ($P < 0.0058$) and three territories ($P < 0.0003$). Calculated optimal thresholds for global MBF and myocardial blood volume resulted in a sensitivity, specificity, and negative predictive value of 100% for detection of three-vessel territory PD. For detection of ≥2 territories with PD, global MBF was superior to other parameters (sensitivity 81.3%, specificity 90.9%, and negative predictive value 94.3%).

**Conclusions:** Semiautomated global quantification of left ventricular MBF during stress dynamic CTMPI shows high diagnostic accuracy for detection of ≥2 vessel territories with PD, facilitating identification of patients with multi-territorial myocardial PD.

**Key Words:** Myocardial perfusion imaging; multidetector computed tomography; coronary artery disease.



**Acad Radiol 2016;** 23:429–437

From the Department of Radiology and Radiological Science, Medical University of South Carolina, Ashley River Tower, MSC 226, 25 Courtenay Drive, Charleston, SC 29425 (J.L.W., F.G.M., U.J.S., A.V.-S., G.M., A.D.MQ., C.N.D.C.); Department of Diagnostic and Interventional Radiology, University Hospital Frankfurt, Frankfurt, Germany (J.L.W.); Institute for Clinical Radiology, Ludwig-Maximilians-University Hospital, Munich, Germany (F.G.M.); Division of Cardiology, Department of Medicine, Medical University of South Carolina, Ashley River Tower, MSC 592, 25 Courtenay Drive, Charleston, SC 29425 (U.J.S.); Department of Radiological Sciences, Oncology and Pathology, University of Rome "Sapienza"—Polo Pontino, Latina, Italy (G.M., P.M.C., C.N.D.C.); Scuola di Specializzazione in Radiodiagnostica, University of Milan, Milano, Italy (P.M.C.); Department of Radiology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea (Y.H.C.); Department of Radiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences, Beijing, China (Y.W.). Received May 1, 2015; revised November 24, 2015; accepted December 8, 2015. Sources of funding: UJS is a consultant for and/or receives research support from Astellas, Bayer, Bracco, GE, Medrad, and Siemens. **Address correspondence to:** U.J.S. e-mail: schoepf@musc.edu


http://dx.doi.org/10.1016/j.acra.2015.12.005

## INTRODUCTION

Stress dynamic computed tomography myocardial perfusion imaging (CTMPI) is a recently developed technique that has been shown to allow for the detection of myocardial perfusion deficits during coronary CT angiography (CCTA) (1–3). Prior studies have established the feasibility of this approach and have demonstrated its capability to accurately evaluate the hemodynamic relevance of coronary artery stenosis in comparison to cardiac magnetic resonance (CMR), nuclear myocardial perfusion imaging (MPI), and invasive coronary angiography (ICA) with or without functional flow reserve (FFR) measurements (1,2,4–11). Thus, the combination of CCTA and CTMPI may allow for the comprehensive noninvasive assessment of coronary artery disease (CAD) and hemodynamic relevance of stenosis during a single examination.

Whereas prior studies have focused on the segmental and territorial evaluation of perfusion deficits on CTMPI (1,11), recently, it was demonstrated that manual global quantitative assessment of myocardial perfusion also correlates with visual segmental analysis and presence of coronary artery stenosis (12). By calculating optimal cutoff values for global left ventricular myocardial blood flow (MBF) and myocardial blood volume (MBV), a recent study reported a sensitivity of 100% for both parameters for the detection of three-vessel perfusion defects (12). However, the diagnostic accuracy of manual or semiautomated global measurements for the detection of one- or two-vessel territories with perfusion deficits remains unknown. Furthermore, it was recently demonstrated that semiautomated segmental quantitative analysis during CTMPI using dedicated three-dimensional (3D) software is feasible and provides similar results compared to manual segmental assessment while allowing for substantial time savings and showing strong agreement with single-photon emission CT (SPECT) (13).

Therefore, we sought to combine both approaches and evaluate the performance of semiautomated software for the analysis of global left ventricular myocardial perfusion during stress dynamic CTMPI. We hypothesized that assessment of global myocardial perfusion using semiautomated 3D software may represent an auxiliary technique for the reliable detection of territorial perfusion deficits in patients undergoing CCTA with little user input. Thus, the purpose of our study was to evaluate the diagnostic accuracy of semiautomated global assessment of quantitative measurements of left ventricular myocardial perfusion derived from stress dynamic CTMPI for the detection of territorial perfusion deficits.

## METHODS

### Patient Population

In this multicenter study, the data of patients from three centers in Asia and North America, who had undergone CCTA and dynamic CTMPI as part of single-center studies, were analyzed. Patients were eligible for this study if they had suspected or known CAD. Exclusion criteria for study participation included contraindications to CT imaging, administration of iodinated contrast media, or adenosine. The respective research study protocols had been approved by the institutional review boards of all participating institutions, and written informed consent had been obtained from all patients prior to enrollment. The dynamic CTMPI examinations during CCTA were performed for research purposes.

### CT Image Acquisition

All image acquisitions were performed on a second-generation dual-source CT system (SOMATOM Definition Flash; Siemens Healthcare, Forchheim, Germany). First, patients underwent CCTA at rest following intravenous administration of 50–80 mL of iodinated contrast agent (concentration 300–370 mg I/mL). No beta-blockers were given. Depending on the patient's heart rate and rhythm, CCTA was performed using retrospective electrocardiogram-gated (ECG-gated) spiral acquisition (patients with arrhythmia), prospectively ECG-gated sequential acquisition (patients in sinus rhythm with a heart rate [HR] > 60 bpm), or prospectively ECG-gated high-pitch (pitch of 3.2) spiral acquisition (patients in sinus rhythm with an HR ≤ 60 bpm).

After 3 minutes of continuous adenosine administration at an infusion rate of 140 μg/kg/min, patients underwent CTMPI. The scan delay was determined using a test bolus injection and set 4–6 s before arrival of the contrast in the thoracic aorta. Data acquisition was performed for 30 s with both x-ray tubes set at 100 kV, a gantry rotation time of 0.28 s, and a tube current of 300 mAs per rotation. CTMPI was performed using an ECG-gated shuttle mode in which the table shifts between two z-positions of the heart. Image acquisition was performed in systole 250 ms after the R-wave. With a defined detector width of 38 mm and a 10% overlap between both imaging positions, the coverage of the acquisition was 73 mm. A total of 14–15 image volumes were acquired during myocardial passage of the contrast media bolus in each patient. CTMPI studies were contrast-medium enhanced by 40–50 mL of iodinated contrast agent (concentration 300–370 mg I/mL) administered at a flow rate of 4–7.5 mL/s to ensure an iodine delivery rate of 1.5–2.25 g I/s.

### Visual Analysis of CTMPI Data

Dynamic CTMPI data were analyzed to identify patients with perfusion defects in no, one, two, or three myocardial territories and were reconstructed with a section thickness of 3 mm and 2 mm increment using a medium smooth convolution kernel ("B30"). Myocardial segments affected by attenuation artifacts due to beam hardening, as well as segments not fully included in the CT perfusion examination volume were excluded from further evaluation. Studies were transferred to a dedicated workstation (Multimodality Workplace, Siemens Healthcare) and analyzed using commercial available software (syngo.via, Siemens Healthcare).