Original Investigations

Comparison of Myocardial Perfusion Evaluation with Single Versus Dual-Energy CT and Effect of Beam-Hardening Artifacts

Patricia M. Carrascosa, MD, PhD, Ricardo C. Cury, MD, Alejandro Deviggiano, MD, Carlos Capunay, MD, Roxana Campisi, MD, Marina López de Munain, MD, Javier Vallejos, MD, Carlos Tajer, MD, Gaston A. Rodriguez-Granillo, MD, PhD

Rationale and objectives: We sought to explore the feasibility and diagnostic performance of dual-energy computed tomography (DECT) versus single-energy computed tomography (SECT) for the evaluation of myocardial perfusion in patients with intermediate to high likelihood of coronary artery disease.

Materials and Methods: The present prospective study involved patients with known or suspected coronary artery disease referred for myocardial perfusion imaging by single-photon emission computed tomography. Forty patients were included in the study protocol and scanned using DECT imaging (n = 20) or SECT imaging (n = 20). The same pharmacologic stress was used for DECT, SECT, and single-photon emission computed tomography scans.

Results: A total of 1360 left ventricular segments were evaluated by DECT and SECT. The contrast-to-noise ratio was similar between groups (DECT 8.8 $\pm$ 2.9 vs. SECT 7.7 $\pm$ 4.2; P = .22). The diagnostic performance of DECT was greater than that of SECT in identifying perfusion defects (area under the receiver operating characteristic curve of DECT 0.90 [0.86–0.94] vs SECT 0.80 [0.76–0.84]; P = .0004) and remained unaffected when including only segments affected by beam-hardening artifacts (area under the receiver operating characteristic curve = DECT 0.90 [0.84–0.96] vs. SECT 0.77 [0.69–0.84]; P = .007).

Conclusions: Our results suggest that myocardial perfusion by DECT imaging is feasible and might have improved diagnostic performance compared to SECT imaging for the assessment of myocardial CT perfusion. Furthermore, the diagnostic performance of DECT remained unaffected by the presence of beam-hardening artifacts.

Key Words: Computed tomography; spectral imaging; dypiridamole.

Until recently, coronary computed tomography angiography (CCTA) was limited to the anatomic assessment of coronary obstructions in patients with low to intermediate likelihood of coronary artery disease (CAD), whereas the functional significance of coronary stenoses remained outside its scope. Several studies have demonstrated the ability of CCTA to perform myocardium perfusion studies by using stress vasodilator agents (1–4). However, the clinical use of stress myocardium computed tomography (CT) perfusion is somewhat limited, mostly by technical issues including beam-hardening artifacts (BHAs), which are originated by the polychromatic nature of x-rays and the energy dependency of x-ray attenuation, and are related to a considerable myocardial signal density (SD) drop at regions in close proximity to highly attenuated structures, thus resembling perfusion defects (5).

With the advent of dual-energy computed tomography (DECT) imaging, BHAs could be reduced with the generation of synthesized monochromatic image reconstruction (6). We therefore sought to explore the feasibility and diagnostic performance of DECT versus single-energy computed tomography (SECT) for the evaluation of myocardial perfusion defects assessed by single-photon emission computed tomography (SPECT) in patients with intermediate to high likelihood of CAD. Furthermore, we sought to compare the diagnostic performance of DECT versus SECT among myocardial regions with high prevalence of BHAs.

Acad Radiol 2015; ■:1–9

From the Department of Cardiovascular Imaging, Diagnóstico Maipú, Av Maipú 1668, Vicente López, B1602ABQ Buenos Aires, Argentina (P.M.C., A.D., C.C., R.C., M.L.d.M., J.V., C.T., G.A.R.-G.); and Baptist Hospital of Miami, Miami, Florida; and Baptist Cardiac and Vascular Institute, Miami, Florida (R.C.C.). Received August 25, 2014; accepted December 23, 2014. We declare that Drs Patricia M. Carrascosa and Ricardo C. Cury are Consultants for GE. There are no competing interests related to the manuscript for any of the other authors. **Address correspondence to:** P.M.C. e-mail: patriciacarrascosa@diagnosticomaipu.com.ar

http://dx.doi.org/10.1016/j.acra.2014.12.019

METHODS

Study Population

The present work was a single-center, investigator driven, prospective study that involved patients with known or suspected CAD referred for myocardial perfusion imaging by SPECT. All patients included were older than 40 years, with stable heart rate and sinus rhythm, able to maintain a breath-hold for 15 seconds; without a history of contrast-related allergy, renal failure, or hemodynamic instability. Additional exclusion criteria comprised a body mass index greater than 32 kg/m^2, a history of previous myocardial infarction within the previous 30 days, percutaneous coronary revascularization within the previous 6 months, chronic heart failure, chronic obstructive pulmonary disease, high-degree atrioventricular block, or low estimated pretest probability of CAD.

Patients were advised to refrain from vasodilator medications for the previous 24 hours, as well as from smoking and caffeine beverages. Coronary risk factors and clinical status were recorded at the time of the CT scan, and clinical variables were defined as indicated by the Framingham Risk Score assessment. The estimated pretest likelihood of obstructive CAD was calculated using the Duke Clinical Score, which includes chest pain features, age, gender, and traditional risk factors. Patients were thus categorized as having low (1%–30%), intermediate (31%–70%), or high (71%–99%) estimated pretest likelihood of obstructive CAD (7,8).

Patients were sequentially scanned using 256-slice SECT (Brilliance ICT; Philips Healthcare, Cleveland, Ohio) or a CT scanner equipped with gemstone detectors with fast primary speed and low afterglow designed for DECT imaging (Discovery HD 750; GE Medical Systems, Milwaukee). The same pharmacologic stress was used for SECT, DECT, and SPECT scans. Dypiridamole (0.56 mg/kg) and iodinated contrast (iobitridol, Xenetix 350; Guerbet, Villepinte, France) were administrated using two independent antecubital intravenous lines. After dypiridamole infusion, aminophylline (1–2 mg/kg) was administrated intravenously to revert the vasodilator effect. The prespecified primary endpoint of the study was to compare the diagnostic performance of DECT versus SECT on a per segment basis using receiver operating characteristic (ROC) curve analyses. Furthermore, we sought to compare the diagnostic performance among segments commonly influenced by the presence of BHAs.

CT Perfusion Acquisition

In line with the primary end point of the study and the population involved (intermediate to high likelihood of CAD), stress myocardial perfusion imaging was performed first and rest imaging 30 minutes after stress imaging.

According to the guidelines of the Society of Cardiovascular Computed Tomography (SCCT) on radiation dose and dose-optimization strategies in cardiovascular CT (9), SECT studies were acquired using the following depending on the acquisition mode (retrospective or prospective) and body mass index.

Among retrospective (stress) acquisitions, maximum tube voltage was adjusted according to the body habitus (100 or 120 kV for patients with body mass index <30 kg/m^2 or greater, respectively). Likewise, tube current was adjusted according to the body habitus (800 or 1000 mAs for patients with body mass index <30 kg/m^2 or greater, respectively). Other scanner-related parameters were a collimation width of 0.625 mm, a slice interval of 0.625 mm, and a pitch of 0.18. Among prospective (rest) acquisitions, maximum tube voltage and current was adjusted according to the body habitus (100 or 120 kV for patients with body mass index <30 kg/m^2 or greater, respectively, and 200–250 mAs, respectively).

Dual-Energy CT

Stress myocardial perfusion imaging was performed after intravenous administration of dypiridamole using prospective electrocardiogram (ECG) gating including ~100 milliseconds of temporal padding aimed to comprise approximately 45%–75% of the R-R interval. DECT was performed by rapid switching (0.3–0.5 milliseconds) between low and high tube potentials (80–140 kV) from a single source, thereby allowing the reconstruction of low- and high-energy projections and generation of monochromatic image reconstructions with 10 keV increments from 40 to 140 keV. Iterative reconstruction was available for every energy level except from 40 and 50 keV (10). Three minutes after dypiridamole administration, a dual-phase protocol with 50–70 mL of iodinated contrast followed by a 30–40 mL saline flush was injected through an arm vein at an injection rate of 4.0–5.0 mL/s according to the vein access. A bolus tracking technique was used to synchronize the arrival of contrast at the level of the coronary arteries with the start of the scan, using a region of interest placed at the ascending aorta and a threshold of 120 Hounsfield units.

For rest-DECT imaging, patients with a heart rate of more than 65 bpm received 5 mg intravenous propranolol if needed to achieve a target heart rate of less than 60 bpm. Image acquisition at rest was performed using the same protocol as for stress-DECT, after sublingual administration of 2.5–5 mg of isosorbide dinitrate.

Single-Energy CT

Stress myocardial perfusion imaging with SECT was performed using retrospective ECG gating (because of the increased heart rate associated with pharmacologic stress) with dose pulsing, an algorithm designed to modulate the tube current according to the ECG during the spiral scan, after intravenous administration of dypiridamole. The same contrast injection protocol as for DECT was used. Iterative reconstruction was performed in all cases.