Attenuation correction in stress-only myocardial perfusion imaging

Aju P. Pazhenkottil, MD,[a] Philipp A. Kaufmann, MD,[a] and Oliver Gaemperli, MD[a]

[a] Cardiac Imaging, Department of Nuclear Medicine, University Hospital Zurich, Zurich, Switzerland

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Despite several technical advances in single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI), attenuation artifacts remain an important concern affecting image quality and diagnostic accuracy. Attenuation artifacts are the result of non-uniform photon attenuation by the human body. Although gender and body habitus may be associated with certain characteristic patterns of attenuation, the large variety in individual anatomy renders photon attenuation often unpredictable. Several strategies have been developed to suppress or correct for non-uniform attenuation in SPECT MPI including prone imaging, integrating findings from gated SPECT, and correction by attenuation maps generated from either external line sources (most commonly Gd-153) or transmission computed tomography (CT) scans. Although attenuation correction (AC) has been demonstrated to improve diagnostic accuracy over non-corrected (NC) images and has advantages over prone imaging with regard to patient comfort, only a limited proportion of cameras in the United States and Europe are equipped with AC. Reasons for this are increased complexity of protocols, higher maintenance costs, and lack of reimbursement. Nonetheless, the use of CT-based AC is growing due to the increased availability of hybrid SPECT/CT scanners worldwide. Compared to line sources, CT-based attenuation correction prevents low-count AC maps and truncation artifacts (obese) or cross-talk with emission data, and allows detailed anatomical evaluation of incidental findings and (if ECG-gating is performed) coronary calcium. The latter may add crucial information on coronary atherosclerosis to complement perfusion findings and improve risk stratification of the patient.

AC is particularly valuable in the setting of stress-only MPI as the corrected images improve the interpretative confidence of the reader and reduce the perceived need for an additional rest study, thereby reducing radiation exposure and improving patient logistics. Hence, the use of AC is strongly advocated for stress-only MPI by US and European recommendations.[1,2] Several reports of stress-only protocols with conventional sodium iodide cameras have demonstrated that the use of AC reduces the need of additional rest imaging by roughly one-third. The use of novel small-footprint cardiac SPECT cameras equipped with ultra-fast cadmium zinc telluride (CZT) detectors has further improved patient comfort and throughput by reducing image acquisition time considerably.[3] Several studies have been conducted to assess different strategies for implementing and evaluating this new detector technology in daily clinical routine—most of them concerning diagnostic accuracy, acquisition time, image quality, and radiation dose.[4-6] However, their use in stress-only protocols and the effect of CT-based AC on interpretative confidence have been only scarcely investigated yet.

In the current issue of the Journal of Nuclear Cardiology, van Dijk and colleagues evaluate the value of CT-based AC in stress-only myocardial perfusion imaging on a SPECT camera with novel CZT detector technology. For this purpose, 107 consecutive patients who underwent stress-optional rest SPECT MPI scan were retrospectively included and images were reconstructed and analyzed in three different manners, namely using NC images only, AC images only, or both AC and NC images, respectively. The prognostic value was

Reprint requests: Aju P. Pazhenkottil MD, Cardiac Imaging, Department of Nuclear Medicine, University Hospital Zurich, Zurich, Switzerland; *aju.pazhenkottil@usz.ch*
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assessed over a mean follow-up time of 47.7 ± 9.8 months. The proportion of scans interpreted as normal increased significantly using AC or NC + AC (from 45% to 72%, and 67%, respectively). Event rates were low for patients with normal scans in all the three groups. However, in abnormal or equivocal scans, event rates were higher for the AC group than those for the NC group (4.3% vs 2.2%).

With their study, Van Dijk et al contribute to the current body of literature emphasizing the important role of AC in stress-only MPI protocols. Their documented increment in interpretative confidence (27%) is in the range of previously published data with conventional sodium iodide cameras. The results of the clinical endpoint analysis have to be considered preliminary, since the trial was clearly not powered for such an analysis. Nonetheless, it is interesting to see that event rates appeared to be very comparable and low for normal scans in all the three groups. However, for abnormal or equivocal scans (i.e., those scans which according to current recommendations would require an additional rest study), event rates were almost twice as high in the AC group compared to the NC group. This finding suggests a better discrimination of normal scans and abnormal scans by AC- compared to NC-stress-only-SPECT. Notably, when NC and AC images were reported and analyzed together, the improved discriminatory capacity of AC was slightly blunted.

Despite the reported advantages of CT-based AC over other methods, it should be emphasized that this method has also introduced new challenges to image processing and interpretation. Misregistration of CT maps and emission data occurs more often than with line sources (because transmission and emission images are not obtained simultaneously) and can cause reconstruction artifacts. Case-to-case quality control of correct superposition of CT and SPECT data and manual correction of misregistration are mandatory for each study. This is even more the case if ECG-gated CT scans are used for AC, since these scans are obtained at mid-diastole and usually during inspiratory breath-hold. Therefore, AC SPECT images should always be interpreted and reported in combination with their NC counterparts in order to identify typical reconstruction artifacts. Although the study by van Dijk suggested better prognostic discrimination with AC only compared to NC plus AC reading, this finding should not be overemphasized based on the lack of statistical power.

In their study, van Dijk and colleagues do not specifically address but rightfully mention other important prerequisites of stress-only imaging. Consideration of ECG-gated data plays an important role in stress-only protocols; only in unequivocally normal perfusion scans with normal left ventricular cavity size, ejection fraction and regional wall motion, and thickening, an additional resting study should be waived. Likewise, a careful selection of patients is emphasized including patients at the lower spectrum of pretest probability without prior myocardial infarction or known LV dysfunction. However, the combination of low-dose CT scans with CZT SPECT offer a number of additional interesting features for stress-only imaging: The use of ECG-gated CT scans for AC allows detection and quantification of coronary calcifications. The absence of any detectable coronary calcium is associated with a very low probability of obstructive coronary artery disease. Thus, a zero calcium score may add further interpretative certainty to the stress-only SPECT study. Furthermore, novel image acquisition protocols with ultrafast CZT SPECT cameras including interval inspiratory breath-hold imaging reduce attenuation artifacts in the inferior wall and may reduce misregistration artifacts between SPECT and AC CT images.[7]

Although the use of AC in SPECT MPI is emerging and there is evidence of superiority in diagnostic confidence and accuracy of AC over non-corrected SPECT MPI, information on the prognostic value of AC on SPECT MPI studies are limited, particularly when using stress-only imaging.[8-10] Hence, the work of van Dijk and co-workers is an important step forward in the direction of patient-centered care promoting stress-only imaging using the latest SPECT technology.

References:

1. Flotats A, Knuuti J, Gutberlet M, Marcassa C, Bengel FM, Kaufmann PA, et al. Hybrid cardiac imaging: SPECT/CT and PET/CT. A joint position statement by the European Association of Nuclear Medicine (EANM), the European Society of Cardiac Radiology (ESCR) and the European Council of Nuclear Cardiology (ECNC). Eur J Nucl Med Mol Imaging 2011;38:201-12.
2. Cerqueira MD, Allman KC, Ficaro EP, Hansen CL, Nichols KJ, Thompson RC, et al. Recommendations for reducing radiation exposure in myocardial perfusion imaging. J Nucl Cardiol 2010;17:709-18.
3. Herzog BA, Buechel RR, Katz R, Brueckner M, Husmann L, Burger IA, et al. Nuclear myocardial perfusion imaging with a cadmium-zinc-telluride detector technique: optimized protocol for scan time reduction. J Nucl Med 2010;51:46-51.
4. Duvall WL, Croft LB, Godiwala T, Ginsberg E, George T, Henzlova MJ. Reduced isotope dose with rapid SPECT MPI imaging: initial experience with a CZT SPECT camera. J Nucl Cardiol 2010;17:1009-14.
5. Mouden M, Timmer JR, Ottervanger JP, Reiffers S, Oostdijk AH, Knollema S, et al. Impact of a new ultrafast CZT SPECT camera for myocardial perfusion imaging: fewer equivocal results and lower radiation dose. Eur J Nucl Med Mol Imaging 2012;39:1048-55.
6. Einstein AJ, Blankstein R, Andrews H, Fish M, Padgett R, Hayes S, et al. Comparison of image quality, myocardial perfusion, and left ventricular function between standard imaging and single-injection ultra-low-dose imaging using a high-efficiency SPECT camera: the MILLISIEVERT study. J Nucl Med 2014;55:1430-7.

7. Buechel RR, Pazhenkottil AP, Herzog BA, Husmann L, Nkoulou RN, Burger IA, et al. Real-time breath-hold triggering of myocardial perfusion imaging with a novel cadmium-zinc-telluride detector gamma camera. Eur J Nucl Med Mol Imaging 2010;37:1903-8.
8. Mathur S, Heller GV, Bateman TM, Ruffin R, Yekta A, Katten D, et al. Clinical value of stress-only Tc-99m SPECT imaging: importance of attenuation correction. J Nucl Cardiol 2013;20:27-37.
9. Pazhenkottil AP, Ghadri JR, Nkoulou RN, Wolfrum M, Buechel RR, Küest SM, et al. Improved outcome prediction by SPECT myocardial perfusion imaging after CT attenuation correction. J Nucl Med 2011;52:196-200.
10. Ardestani A, Ahlberg AW, Katten DM, Santilli K, Polk DM, Bateman TM, et al. Risk stratification using line source attenuation correction with rest/stress Tc-99m sestamibi SPECT myocardial perfusion imaging. J Nucl Cardiol 2014;21:118-26.