Moving ahead with CZT technology

Dominik C. Benz, MD,^a and Ronny R. Buechel, MD^a

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

Received Oct 26, 2015; accepted Oct 26, 2015
doi:10.1007/s12350-015-0321-2

See related article, pp. 514–526

Patient motion is well-recognized as a potential source of error in single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI) that results in undesirable effects ranging from loss of resolution and image blurring to artifactual defects or even non-interpretable datasets.^{1–3} Obviously, the optimal approach to reduce the incidence and severity of such artifacts would be prevention of patient motion altogether. While placing patients in a comfortable position constitutes a mandatory precautionary measure, it does not completely prevent motion due to increasing patient discomfort during the course and duration of the entire SPECT image acquisition. In view of the above, it may at first glance appear that the latest generation of gamma cameras with cadmium-zinc-telluride (CZT)-based semiconductor detector technology may offer some advantage with this regard as they allow a significant reduction of acquisition times (i.e., a reduction to 2–3 min) due to the combination of increased overall system sensitivity and the miniaturized detectors that enable a stationary camera design without the need of rotation of the detectors around the patient.^{4–6}

However, a number of new aspects concerning motion artifacts and detection arise from these novel CZT scanners that should be taken into consideration: Firstly, any patient motion will simultaneously affect all the detectors and, within the drastically shortened image acquisition time, will have a relatively higher negative impact on image quality than during the longer acquisition with conventional SPECT cameras simply

because counts acquired during such patient movements will affect a greater proportion of the overall count statistics. The latter may be particularly true for motion patterns such as “bounce” movement (i.e., the single occurrence of returning motion). Secondly, the substantially improved spatial resolution of CZT scanners over conventional SPECT cameras, may amplify the impact of motion on image quality and artifacts. Finally, while a variety of techniques have been established for motion detection and correction of SPECT-MPI on conventional Anger cameras, these are not directly applicable to CZT cameras due to the different hardware design incorporating a stationary detector setup. With the increasing use of CZT scanners, however, the need for accurate motion detection and correction becomes obvious. After all, an estimated 400 CZT cameras are currently already in use with an expected increase of approximately 100 devices per year.

In the current issue of the Journal of Nuclear cardiology, Shelley et al. embrace the topic of motion detection and correction for CZT cameras with an elegantly designed and meticulously performed study including a phantom study for validation and subsequent translation into clinical routine. In the phantom study, motion during myocardial perfusion images—as subtle as 11 mm—resulted in blurring of the left ventricular walls and may have mimicked perfusion defects as large as 5.5%; a cut-off that may clinically be interpreted as ischemia due to significant coronary artery disease.⁷ To detect and quantify motion, the authors evolved two methods: after re-binning list-mode data to series of 30 s-images, serial 30 s-images either from (1) raw data as acquired by individual detectors or from (2) the entire three-dimensional reconstructed datasets were co-registered, and their translations to the first image were measured. Both of the applied methods reliably and consistently detected and quantified motion—with a maximum absolute error between the actual and the measured shift below 2 mm. As an extension to the three-dimensional motion detection technique, the authors corrected for motion by summing the co-

Reprint requests: Ronny R. Buechel, MD, Cardiac Imaging, Department of Nuclear Medicine, University Hospital Zurich, Zurich, Switzerland; ronny.buechel@usz.ch

J Nucl Cardiol 2016;23:527–8.

1071-3581/\$34.00

Copyright © 2015 American Society of Nuclear Cardiology.

registered 30 s-images to generate one final image. In the quantitative analysis, all relevant (i.e., $\geq 5.5\%$) motion-induced perfusion defects were eliminated after motion correction. When qualitatively assessed, only one motion artifact persisted after motion correction. Subsequent to validation using phantom data, the above mentioned methods for motion detection and correction were translated to the clinical setting with 40 patients. The authors demonstrated that significant motion (≥ 8 mm)—quantified consistently by either of the two methods for motion detection—could be measured in as many as 10% of the patients in the superior–inferior direction. In half of these patients, motion was suspected of having introduced a reversible perfusion defect since motion correction led to normalization of the MPI datasets. Of note, patient movement within the lateral or anterior–posterior direction did not lead to significant artifacts.

This study is of importance because it addresses an issue which until now may have received too little attention. The introduction of semiconductor detector technology using synthetic crystals composed of CZT undeniably constituted a revolutionary milestone in technical innovation for nuclear MPI, offering a variety of interesting new possibilities ranging from dynamic SPECT imaging for non-invasive quantitation of myocardial blood flow,⁸ over respiratory triggering,⁹ to low isotope dose SPECT with significantly reduced ionizing radiation exposure.¹⁰ However, particularly the strive for a further reduction in radiation dose exposure will in turn inevitably again lead to a future increase in acquisition times because with the current CZT system sensitivity very short acquisition times of only 2 or 3 min may not yield sufficient count statistics if the isotope dose is substantially reduced. Any increase in acquisition times, however, renders imaging more prone to motion artifacts. Against this background, any solutions to address the very basic and well-known sources for potential artifacts in MPI such as motion detection and correction are highly welcome to ensure the successful and ongoing evolution of nuclear cardiac imaging with CZT scanners.

Disclosure

The University Hospital Zurich holds a research contract with GE Healthcare.

References

1. Friedman J, Berman DS, Van Train K, Garcia EV, Bietendorf J, Prigent F, et al. Patient motion in thallium-201 myocardial SPECT imaging. An easily identified frequent source of artifactual defect. *Clin Nucl Med* 1988;13:321-4.
2. Cooper JA, Neumann PH, McCandless BK. Effect of patient motion on tomographic myocardial perfusion imaging. *J Nucl Med* 1992;33:1566-71.
3. Germano G, Chua T, Kavanagh PB, Kiat H, Berman DS. Detection and correction of patient motion in dynamic and static myocardial SPECT using a multi-detector camera. *J Nucl Med* 1993;34:1349-55.
4. Bocher M, Blevis IM, Tsukerman L, Shrem Y, Kovalski G, Volokh L. A fast cardiac gamma camera with dynamic SPECT capabilities: Design, system validation and future potential. *Eur J Nucl Med Mol Imaging* 2010;37:1887-902.
5. Buechel RR, Herzog BA, Husmann L, Burger IA, Pazhenkottil AP, Treyer V, et al. Ultrafast nuclear myocardial perfusion imaging on a new gamma camera with semiconductor detector technique: First clinical validation. *Eur J Nucl Med Mol Imaging* 2010;37:773-8.
6. Imbert L, Poussier S, Franken PR, Songy B, Verger A, Morel O, et al. Compared performance of high-sensitivity cameras dedicated to myocardial perfusion SPECT: A comprehensive analysis of phantom and human images. *J Nucl Med* 2012;53:1897-903.
7. Slomka PJ, Nishina H, Berman DS, Akincioglu C, Abidov A, Friedman JD, et al. Automated quantification of myocardial perfusion SPECT using simplified normal limits. *J Nucl Cardiol* 2005;12:66-77.
8. Ben-Haim S, Murthy VL, Breault C, Allie R, Sitek A, Roth N, et al. Quantification of myocardial perfusion reserve using dynamic spect imaging in humans: A feasibility study. *J Nucl Med* 2013;54:873-9.
9. 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.
10. Duvall WL, Croft LB, Ginsberg ES, Einstein AJ, Guma KA, George T, et al. Reduced isotope dose and imaging time with a high-efficiency CZT SPECT camera. *J Nucl Cardiol* 2011;18:847-57.