Can Advances in Nuclear Cardiology Hardware Overcome the Challenges of Imaging Obese Patients?

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Received Sep 16, 2014; accepted Sep 17, 2014

doi:10.1007/s12350-014-0005-3

See related article, pp. 266–275

Worldwide, the estimated total number of obese people is 671 million, with the United States having the largest proportion.¹ Although there is an urgent global need to combat obesity, the prevalence of this disease—which is a well-recognized risk factor for both cardiovascular disease and cancer—continues to increase. Adding to the burden of this disease are the complexities and costs related to the diagnostic evaluation of obese individuals with suspected or known coronary artery disease (CAD). All non-invasive imaging techniques—including, stress echocardiography, cardiac CT, and SPECT myocardial perfusion imaging—have inherent limitation related to imaging obese individuals. To address these issues, there have been various technological advances aimed to improve image quality among obese individuals.^{2–4}

Arguably, one of the most important such advances in the field of nuclear cardiology has been the introduction of a new generation of cameras using solid-state detectors. In particular, the cadmium zinc telluride (CZT) detector directly converts gamma radiation to an electronic signal and thus avoids the need for a scintillating crystal or photomultiplier tubes. Using this technology, two vendors (GE and Spectrum Dynamics) have introduced cameras with CZT detectors, with each

having significant differences in collimator and camera design.⁵ Studies using these cameras have shown that in comparison to conventional sodium iodide detectors, CZT detectors offer improved efficiency, superior count sensitivity, and increased spatial resolution, as also detailed in the Table 1. To date, a small study of mostly non-obese patients suggests that these characteristics also translate into improved diagnostic accuracy vs conventional SPECT,⁶ and one study showed modest concordance between ischemia detected by a CZT scanner with fractional flow reserve.⁷

However, do the aforementioned advances in nuclear cardiology hardware also provide superior image quality and diagnostic accuracy when imaging obese patients?

While the reduced image quality observed in obese patients is most often due to anthropometric parameters which result in excessive soft tissue attenuation, the lower myocardial fraction of injected activity found in obese individuals⁸ may also be due to tracer kinetic parameters such as the myocardial extraction fraction. It, therefore, follows that the ideal camera to image obese individuals would have a high sensitivity, as well as robust methods to correct (or correctly identify) attenuation artifacts.

Despite the improved image quality observed with CZT cameras, it has been reported (not surprisingly) that when a fixed tracer dose is administered using the multipinhole collimator, obese individuals were more likely to have degraded image quality and lower photon counts.⁸ Importantly, this difference was eliminated when using a weight-dependent tracer dose.⁹

Gimelli et al¹⁰ evaluated the diagnostic accuracy of 148 patients (mean BMI 39 kg; 87% male) who underwent SPECT MPI using the multipinhole detector and observed “very good” or “excellent” image quality in all patients. Among 103 patients who underwent

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J Nucl Cardiol 2015;22:276–8.

1071-3581/\$34.00

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Table 1. Advantages and limitations of the parallel-hole collimator CZT SPECT camera

Feature	Comment/explanation
Advantages	
Increased count sensitivity	Parallel-hole tungsten collimators are shorter and have large square holes (2.26 mm diameter) resulting in larger acceptance angle ¹⁷
Increased spatial resolution (~5 mm)	Intrinsic resolution: 1 CZT detector element (2.46 mm × 2.46 mm) for each collimator hole Extrinsic resolution: increased number of viewing angles allowing for improved modeling of the probability function ¹⁷
Shorter acquisition time	Due to increased sensitivity of detector
Patient comfort	Due to patient positioning and shorter exam time
Lower radiation dose	Even greater reduction in dose can be achieved by imaging patients longer, provided that this can be accomplished without patient motion ¹⁸
Limitations	
No attenuation correction	Use of upright and supine imaging should be used as it is helpful in mitigating some attenuation artifacts
No coronary artery calcium scoring	While not yet established, future capabilities to detect abnormalities in coronary flow reserve may offer a method to detect non-flow limiting CAD ¹⁹

invasive angiography, they reported an overall sensitivity of 92% and specificity of 67% to detect $\geq 70\%$ stenosis.

Subsequently, a study by Fiechter et al suggested that when using a similar multipinhole collimator CZT camera, 81% of morbidly obese patients ($\text{BMI} \geq 40 \text{ kg/m}^2$) had non-diagnostic image quality, mainly due to truncation artifacts which can occur when the heart is out of focus or out of the field of view. In this group, image quality improved when employing attenuation correction (with decrease in non-diagnostic scans to 55%), or when repositioning selected patients ($n = 8$).¹¹ However, even when employing these techniques, superior image quality was obtained when patients were imaged using a conventional A-SPECT camera. Should these results be extrapolated to all CZT scanners or can this limitation be attributed to the smaller field of view afforded by the pinhole collimation geometry?

In this issue of the Journal of Nuclear Cardiology, Nakazato et al¹² have answered this question by evaluating the image quality and diagnostic performance of the CZT parallel-hole SPECT-MPI scanner for detecting coronary artery disease (CAD) among 118 obese patients ($\text{BMI} \geq 35 \text{ kg/m}^2$). Patients were enrolled from three centers in the United States and had a mean BMI 43.6 kg/m^2 , average age of 55 years, and prevalence of diabetes of 30%. Overall, 67 patients underwent invasive coronary angiography (ICA) and 51 were determined to have a low likelihood of CAD, and were thus used for determining the normalcy rate, a surrogate of specificity.

When considering the imaging protocol, the vast majority of patients were imaged using a $^{99\text{m}}\text{Tc}$ -sestamibi protocol. Similar to Fiechter et al, the average dose was 10.8 and 36.5 mCi at rest and stress, respectively. The length of the acquisition time varied from 6–12 minutes for the rest images and 2–6 minutes for the stress images. In order to help mitigate attenuation-related artifacts, stress images were acquired in both the upright and supine positions.^{13,14} In addition to standard semi-quantitative visual scoring techniques, quantitative perfusion was assessed using the total perfusion deficit (TPD), a measure which is based on both defect extent and severity. Abnormal studies were defined when the TPD was $>5\%$ of the myocardium or when the combined TPD from combining both supine and upright images was $>3\%$.

Based on these parameters, Nakazato et al found a high subjective image quality without any difference in image quality across different BMI categories (i.e., 35–39.9; 40–44.9; $\geq 45 \text{ kg/m}^2$). In fact, as opposed to Fiechter et al, none of the patients had a non-diagnostic SPECT scan. While such results are promising, high image quality does not necessarily imply high accuracy, and thus Nakazato et al also examined the diagnostic accuracy of SPECT MPI. Among the 67 patients who underwent ICA (using the combined upright and supine TPD assessment), the observed sensitivity and specificity to detect $\geq 50\%$ stenosis were 80% and 82%, respectively. Similar accuracy was also found when using a visual expert read.

Overall, these results indicate a good diagnostic accuracy for this sub-group of patients who are

notoriously challenging to image, particularly when allowing for post-test verification bias (which increases sensitivity and decreases specificity) and when considering the imperfect correlation between anatomical measures of stenosis and myocardial ischemia.¹⁵ Thus, this study supports the use of SPECT MPI using a CZT detector with a dedicated parallel-hole collimation system as a first-line testing option for obese patients who have an appropriate indication for MPI. Since PET MPI¹⁶ and cardiac MRI² have also been shown to provide adequate image quality and prognostically important findings in obese patients, future research should compare the diagnostic accuracy of the parallel-hole collimator CZT SPECT camera against these modalities.

Of course, we can pause to reflect: would it not be simpler if we had more effective interventions to avoid obesity? Sadly, for better or worse, complex technological imaging advances seem to be far more feasible at this time, and therefore, the need and inherent challenges related to imaging obese patients will remain important issues facing clinicians, imagers, and their patients.

Conflicts of interest

No disclosures or conflicts of interests.

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