Diagnostic implications of CZT SPECT and impact of CT attenuation correction

Andrew Peters, MD,[a] Jeevan Kumar, MD,[a] and Pravin V. Patil, MD[a]

[a] Section of Cardiology, Department of Medicine, Lewis Katz School of Medicine at Temple University, Philadelphia, PA

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In the current issue, Kennedy et al.[1] further validate cadmium-zinc-telluride (CZT) SPECT, including the use of customized databases for automated perfusion scoring. They also demonstrate the utility of CT attenuation correction to reduce false positives and improve diagnostic accuracy. They examined three groups of patients, performing a comparison of CZT and conventional SPECT, establishing a customized database for automated perfusion scoring with CZT, and demonstrating the impact of CT attenuation correction (CTAC) in CZT SPECT. While there have been many studies comparing conventional SPECT to invasive angiography and CZT SPECT to invasive angiography, not many have directly compared them in the same population.

CZT VERSUS CONVENTIONAL SPECT

Single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) is an important non-invasive tool for the evaluation of coronary artery disease (CAD). The relationship of functional ischemia on non-invasive testing and angiographic disease on invasive angiography has been debated heavily, but strong evidence supports the use of stress MPI for diagnosis and prognosis of CAD in certain patients. SPECT MPI has its limitations, such as attenuation artifact and image resolution, which can affect the predictive value and impact the clinical utility.

Conventional SPECT consists of a scintillation detector of sodium iodide (NaI) crystals. These cameras have been validated with good sensitivity and specificity leading to widespread clinical use. Conventional SPECT MPI has a sensitivity ranging between 0.82 and 0.91, and specificity ranging between 0.70 and 0.90.[2] During the first decade of the twenty first century, CZT SPECT systems emerged promising ultrafast acquisition, dose reduction, and similar diagnostic accuracy. The direct conversion of gamma radiation into signal by the semiconductor ensured improved image fidelity.

CZT SPECT has been discussed extensively in the literature since cameras have a higher sensitivity compared to conventional cameras and reduced imaging time.[2] Many of these studies have assessed the diagnostic performance of MPI with CZT cameras (Table 1).[1,3–8] Further, in a meta-analysis by Nudi et al., the sensitivity of CZT SPECT was found to be range between 0.78 and 0.89 and the specificity ranged from 0.62 to 0.76.[9] While the sensitivity is comparable to prior studies, the specificity is lower. Neill et al. further emphasized this with a direct comparison of CZT to conventional SPECT MPI in patients with correlative invasive angiography. CZT SPECT again had superior sensitivity but decreased specificity when compared to conventional SPECT.[8] It is speculated that the lower specificity of CZT imaging is due to the practice of performing upright imaging, which may enhance patient comfort but results in more abdominal attenuation artifact, as well as the clinical tendency for use in an obese patient subgroup.

Kennedy et al.[1] demonstrate a reasonable correlation between CZT and conventional NaI scanners. Their data are in agreement with prior studies that indicate CZT could be associated with lower specificity and a higher number of false positives. Further, they provide low-intermediate risk patient data that support the use of

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Reprint requests: Pravin V. Patil MD, Section of Cardiology, Department of Medicine, Lewis Katz School of Medicine at Temple University, 9th Floor Parkinson Pavilion, 3401 N. Broad Street, Philadelphia, PA 19140; *pravin.patil@tuhs.temple.edu*
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Table 1. Comparison of CZT and conventional SPECT

Author	Type	*n*	SRS	SSS	Sensitivity (%)	Specificity (%)
Kennedy et al.[1]	CZT	80	2.91 ± 5.06	5.56 ± 5.95	N/A	N/A
	CZT (Custom Database)		1.78 ± 4.47	3.64 ± 5.41		
	NaI		1.95 ± 4.15	3.76 ± 5.02		
Barone-Rochette et al.[3]	CZT	214	3.1 ± 4.3	8.0 ± 4.9	94	50
Pourmoghaddas et al.[4]	CZT	108	7.6 ± 3.3	8.33 ± 2.97	N/A	N/A
	NaI		8.8 ± 2.9	9.62 ± 2.28		
Gimelli et al.[5]	CZT	248	2 ± 2	9 ± 5	89	78
Nishiyama et al.[6]	CZT	276	5 ± 8	9 ± 8	87	50
Gimelli et al.[7]	CZT	137	3 ± 3	10 ± 5	95	77
Neill et al.[8]	CZT	53	N/A	N/A	89	57
	NaI				86	77

a separate custom database for CZT automated perfusion scoring, which potentially could improve specificity. It will be important for further research to be performed with a higher risk cohort. The authors also incorporated CTAC into their analysis, validating its use.

ROLE FOR CT ATTENUATION CORRECTION

SPECT MPI is susceptible to attenuation artifacts from tissues such as breast, diaphragm, abdomen, and lateral chest wall that reduce specificity.[10,11] Numerous techniques have been shown to reduce attenuation artifact including breast binding, prone imaging, and attenuation maps created by external sources. External fixed line source attenuation correction (AC) using most frequently gadolinium-153 but also cobalt-57, barium-133, americium-241, and technetium-99m has been used.[12] Nishiyama et al. demonstrated a technique involving combined supine and prone SPECT acquisition could reduce the false-positive rate associated with supine image acquisition.[6] Supine and upright imaging with CZT in obese patients has also demonstrated diagnostic accuracy for CAD.[13,14] Although these techniques have been used, more recently hybrid SPECT/CT systems allow for high-quality attenuation maps due to improved signal-to-noise ratio and better resolution.[15]

CTAC for conventional SPECT imaging has been validated to improve diagnostic accuracy and risk stratification compared with non-attenuation (NAC) corrected imaging.[16–18] CTAC has the advantage over line source AC in that there is higher photon flux, minimizing the interaction with the SPECT radionuclide without decay, and overall reduced scan times.

CZT SPECT is becoming more prolific in clinic practice due to the advantages of improved image fidelity and shorter scan times compared with NaI SPECT.[19] Despite these apparent benefits, CZT is still susceptible to attenuation artifact. Liu et al. used an anthropomorphic torso phantom and found that CZT had higher myocardial count sensitivity, better signal-to-noise ratio, and superior uniformity of overall myocardial tracer uptake compared to NaI; however, CZT was more susceptible to inferior and inferolateral attenuation with lower normalized uptake compared to the NaI camera in the anthropomorphic torso model to simulate a male patient.[20] Similarly, Herzog et al. reported predominant artifacts in the right coronary artery territory in males.[21] In contrast, CZT performed better than the NaI camera in imaging anterior defects.[20] This phenomenon may be explained by the design of the CZT camera, since the pinhole collimator is closest to the linear source in the anterior position and furthest in the right lateral position.

Multiple studies have assessed the diagnostic performance of CZT SPECT with CTAC, using invasive coronary angiography as a comparator. Van Dijk et al. retrospectively looked at 107 patients with low to intermediate probability of CAD that underwent stress only MPI. Diagnostic confidence increased using CTAC as 80% of scans were interpreted as normal or abnormal, rather than equivocal, versus 57% of scans without AC ($P < 0.001$).[22] Caobelli et al. looked at 60 patients, 44 of which underwent coronary angiography, to compare the performance of CZT with and without CTAC. Interestingly, the authors found significantly improved diagnostic accuracy in the RCA territory ($P = 0.002$) but not in the LAD ($P = 0.35$) or LCx ($P = 0.08$)

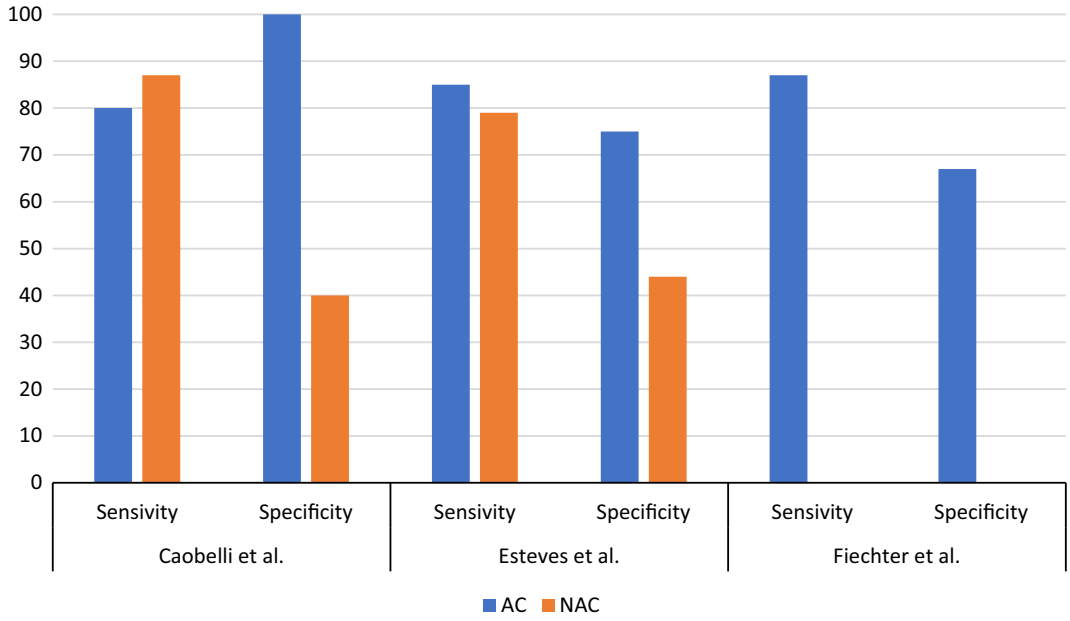

Figure 1. Effect of CT attenuation correction on the diagnostic accuracy of CZT SPECT.

territories.[23] Esteves et al. investigated a subset of 55 patients that underwent coronary angiography within 2 months of CZT SPECT. In their primary analysis, there was a non-significant difference in specificity for obstructive CAD between CTAC and NAC (75% versus 44%; $P = 0.15$).[24] However, in a secondary analysis, the authors found that with quantitative analysis for all three vascular territories, NAC specificity was lower than CTAC (63% versus 78%, $P = 0.02$) Finally, Fietcher et al. looked at 66 patients that underwent CZT SPECT/CT and catheterization within 3 months. The authors reported that with visual analysis the sensitivity/specificity of CZT SPECT was 87%/67% and that with semi-automated analysis the sensitivity/specificity was 74%/67%.[25] Overall, these studies reported high sensitivities and reasonable specificities (Figure 1);[23–25] however, the number of patients in each study was limited.

Kennedy et al.[1] add to the limited body of literature on the use of CTAC in CZT SPECT. They found that AC significantly decreased the SSS and SRS in men when compared with NAC, but not in women. This is in agreement with the current literature and highlights that CZT is more susceptible to inferior attenuation artifact that can masquerade as an RCA territory perfusion abnormality. Although invasive angiographic correlation was not performed by the authors, their data suggest CTAC may lead to a reduction in unnecessary invasive procedures.

Disclosure

The authors report no conflict of interest.

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