The state of the future is solid

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The Anger camera, based on thallium-doped sodium iodide detection of gamma radiation, has been the foundation of cardiac imaging for more than 50 years.[1,2] It remains the bedrock of our profession. Numerous enhancements to the original Anger camera design, such as the advance from planar imaging to multi-detector single-photon emission computed tomography (SPECT), as well as the introduction of new radiopharmaceuticals, attenuation correction, and advanced reconstruction algorithms have resulted in significant improvements in diagnostic accuracy of perfusion imaging.[3-12] Notwithstanding all of these major improvements, the basic scintillation detector design of the camera has remained virtually unchanged. However, there is now a new kid on the block.

In the decades that followed the introduction of the original sodium iodide crystal scintillation detector camera, multiple head systems emerged that allowed more rapid acquisition of the angles of acquisition, and tomographic reconstruction became the new state of the art.[5] While 3-headed systems were proposed, developed, and used, the dual-headed SPECT camera became the industry standard with the best combination of cost and diagnostic efficiency. The availability of more powerful, faster, and less-expensive computer systems (a trend that continues to this day) and more sophisticated reconstruction algorithm approaches further advanced cardiac imaging.[10-16] However, there was always an interest in the development of new imaging crystals to avoid the numerous problems that exist with sodium iodide-based detectors such as hydrophilicity, temperature instability, etc.[17-21] While a number of other crystal types were proposed to replace sodium iodide, cadmium zinc telluride (CZT) has emerged as a top contender in the field. While still expensive, it is anticipated that, in time, cameras using these new solid-state detectors will become more affordable for cardiac SPECT imaging.

The nuclear imaging camera utilizing CZT detectors is the latest in cardiac SPECT camera technology and promises to revolutionize cardiac imaging. In some systems, the camera configuration is such that the detectors remain stationary while acquiring all the angles necessary for tomographic reconstruction through the use of cardiac focusing multi-pinhole collimators. These new detectors represent a radical advancement since Hal Anger developed the first gamma camera.

There are three major benefits to cameras that use the CZT detector systems. First, the fact that the detector system does not move simplifies gantry design and head alignment issues as well as maintenance. Secondly, because the detectors have such good sensitivity, far greater than sodium iodide, scanning times can be reduced thereby enhancing patient comfort, possibly decreasing movement-based artifact and improving patient throughput in a busy nuclear cardiology laboratory. Image quality potentially would improve in obese subjects since count density increases at any dose compared with a conventional camera. One additional important promise of these solid-state detectors is that the higher sensitivity reduces the dose needed for diagnostic studies thereby decreasing radiation exposure to patients. A number of clinical studies have already demonstrated the ability to obtain excellent quality

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cardiac images with reduced doses of technetium-based perfusion agents.[20,21]

In this issue of the Journal, Oldan, Shaw, Hoffman, and colleagues from Duke University demonstrate the prognostic accuracy of images obtained using a CZT camera in a large patient cohort.[22] In this retrospective analysis, the authors compared the cardiac event rate of patients who had gated SPECT myocardial perfusion studies performed on either a CZT camera with those performed on a conventional Anger camera. The studies were evaluated in a semi-quantitative fashion to determine the overall defect burden. Approximately 2000 patients were followed for up to 2 years following the endpoint of death or non-fatal myocardial infarction. The prognostic performance of perfusion studies obtained from each camera system was evaluated based on image interpretation by experienced readers as well as by the semi-quantitative evaluation. The authors found no significant differences between patients imaged on the two different camera systems except for the fact that large patients (>250 pounds) were imaged more frequently on the conventional camera system due to gantry size limitations of the CZT camera. While myocardial perfusion imaging results were shown to be a significant predictor for the composite endpoints of death and myocardial infarction, the type of camera used for imaging had no effect on outcome. The authors conclude that the prognostic information obtained from stress myocardial perfusion imaging with the CZT camera was equivalent to scans obtained with the conventional gamma camera.

As pointed out by the authors, several important limitations in the study design may have an impact on extrapolation of the results obtained to real-world practice. First of all, the study was retrospective, without randomization of patients to the type of scanner. This is a fairly big issue, since randomization has been shown to be the most appropriate approach for comparing drugs, devices, and technology.[23] An alternative to randomization would have been to scan patients on both cameras, which would have no effect on patient dose since the same radiopharmaceutical dose could have been used. Then, individual patient results could have been compared with both cameras and defect size could have been directly compared. However, as pointed out above, larger patients were disproportionately assigned to the conventional camera as the current generation of CZT cameras limits patient girth. Analysis of patient results accounting for size did not change the conclusion of the study. Finally, while the use of the CZT camera potentially has the ability to reduce radiopharmaceutical dose, patients in this study were given equivalent doses of perfusion agents regardless of the camera they were studied on. Although this allowed the CZT camera to perform imaging up to 6-7 times faster than the conventional camera, it did not allow for evaluation of its performance with a reduced dose. While acquisition time with the CZT camera would be prolonged if this study had used lower doses of radiopharmaceuticals, it is likely that it would still be considerably faster than conventional cameras. However, the prognostic performance using low-dose approaches will need to be established. Finally, it is notable that the number of abnormal studies in this cohort of patients was low suggesting that this may have been a relatively low-risk population (despite a 6% on adjusted event rate).

In addition to the above limitations, the cameras used in this study employed significantly different imaging and reconstruction techniques. The conventional Anger camera used a step-and-shoot protocol and filtered back projection with a Butterworth filter for image reconstruction. In contrast, the CZT camera used a stationary pinhole design with a proprietary maximum likelihood iterative reconstruction. Iterative reconstruction has been shown to be superior to filtered back projection, and most conventional cameras are now able to use these more advanced algorithms which enhance image contrast and reduce noise.[13-17]

In summary, SPECT cameras using solid-state CZT detectors represent a significant advance in nuclear cardiology imaging. The study by Oldan et al is the first study to compare the real-life performance of this new technology and demonstrates equivalence with conventional cameras.[22] We look forward to additional studies comparing the performance of this technology addressing the noted limitations. Adoption of this new technology should be rapid as the financial barriers to entry decrease. We should recognize that the advances in nuclear camera designs have occurred because many engineers, scientists, radiochemists, and clinicians have contributed to the science and discovery in nuclear cardiology. If Hal Anger were alive today, we are confident that he would agree with us that the future of nuclear cardiology is solid (state) and bright.

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