Attenuation correction in multipinhole-CZT gamma camera

Differences in attenuation pattern in myocardial SPECT between CZT and conventional gamma cameras. Oddstig J, Martinsson E, Jogi J, Engblom H, Hindorf C. *J Nucl Cardiol.* 2018.

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INTRODUCTION

Practitioners of nuclear cardiology become familiar with their equipment. This is true for conventional SPECT systems as well as high-sensitivity systems with unique detectors and collimation. This editorial is prompted by an article by Oddstig et al that presents the differences in attenuation patterns between standard SPECT and a multi-pinhole CZT SPECT system.[1]

As nuclear technologists acquire scan after scan, they become more and more comfortable with the patient set-up and the procedures required to acquire a quality scan. As physicians interpret scan after scan they learn to look for subtle clues in the images that might indicate patient abnormalities or problems with the acquisition. Problems with the acquisition might include patient motion, improper placement of EKG leads for cardiac gating, or poor positioning of the patient in the scanner. Patient-specific abnormalities may include unusual orientation of the heart within the patient's chest or body habitus where overlying attenuating tissue eclipses part of the heart resulting in artefactual defects that mimic those of perfusion deficits.

The majority of SPECT systems in use today for nuclear cardiology utilize two sodium-iodide (NaI) scintillation cameras mounted at 90° to each other with parallel-hole collimation. This configuration allows a 180° acquisition (45° left-anterior- oblique to 45° left-posterior oblique) by rotating the gantry through 90°. Having used this technology for many years, clinicians have become adept at identifying artifacts in reconstructed images by examining the planar projections that make up the raw data for the scan. Patient motion can be identified by watching the projections in cine mode and looking for a shift in position from frame to frame. Breast attenuation may be identified by looking for a shadow of the breast covering the anterior wall of the heart in the cine display while diaphragmatic attenuation presents as a loss of counts in the inferior wall. Correlation of findings in the projection data and tomographic images can go a long way in artifact identification.

High-sensitivity SPECT systems have been introduced with direct-conversion solid-state detectors made of Cadmium Zinc Telluride (CZT). The CZT SPECT systems available today are cardiac-optimized systems which have been recognized for having certain advantages over conventional SPECT cameras including faster scanning, lower radiation dose, and high image quality due to the characteristics of solid-state detectors and static multi-pinhole collimation, among others. The two main advantages of CZT as a detector are that it has much better energy resolution than NaI scintillation cameras with photomultiplier tubes and its compact size allows construction of compact, pixelated detector

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modules. This compactness, in turn allows the use of unique, high sensitivity, collimation.[2,3]

The similarity of the two CZT-based high-sensitivity SPECT systems available today ends with the detector material. They have two very different collimation schemes and system designs. One of these systems uses nine columnar detectors mounted in a 180° arc around the patient with very high-sensitivity parallel-hole collimation (D-SPECT®, Spectrum Dynamics Medical). During acquisition each detector sweeps through an arc confined to the region of the heart, further maximizing counts. In this system, the patient typically sits in a semi-upright position. A second acquisition may be performed with the patient in a near supine position. Comparison of the SPECT images in the two positions can help the clinician distinguish between true defects and attenuation artifacts.

The CZT system central to the manuscript that prompted this editorial uses 19 square CZT detectors, each with a single tungsten pinhole collimator (Discovery 530c, GE Healthcare).[1] The detector is arranged in three parallel rows with the center row (9 detectors in a 180° arc) perpendicular to the table. During acquisition, this row is centered on the patient's heart. The two adjacent rows (5 detectors each) are oriented so that they image from above and below the centerline (giving a three-dimensional acquisition). Unique to this system, there is no detector motion during acquisition. In addition to the standard supine images, prone images may be acquired as an aid in identifying attenuation artifacts. CT-based attenuation correction is available either through a SPECT/CT option or by importing CT images from a remote CT scanner.[4–6]

CZT SPECT of either configuration presents a learning curve to the clinician. Neither system produces traditional planar projections because both acquire several images simultaneously over a 180° arc. In the D-SPECT system, the patient sits upright and diaphragmatic and breast attenuation will differ from a standard prone position. The Discovery 530c acquires 19 pinhole projections simultaneously, 5 of the detectors image from below the heart, 9 are in-line with the heart and 5 from above the heart. Clinicians used to traditional cameras may have trouble adapting to pinhole images, particularly those made from out-of-plane views. Since each projection covers the full duration of the scan, patient motion will not be readily apparent. The two systems are so different in their configurations that one must be careful not to attribute anything other than high-sensitivity to ''CZT SPECT systems.'' They are as different from each other as each of them is different from a standard, dual-detector, SPECT system.

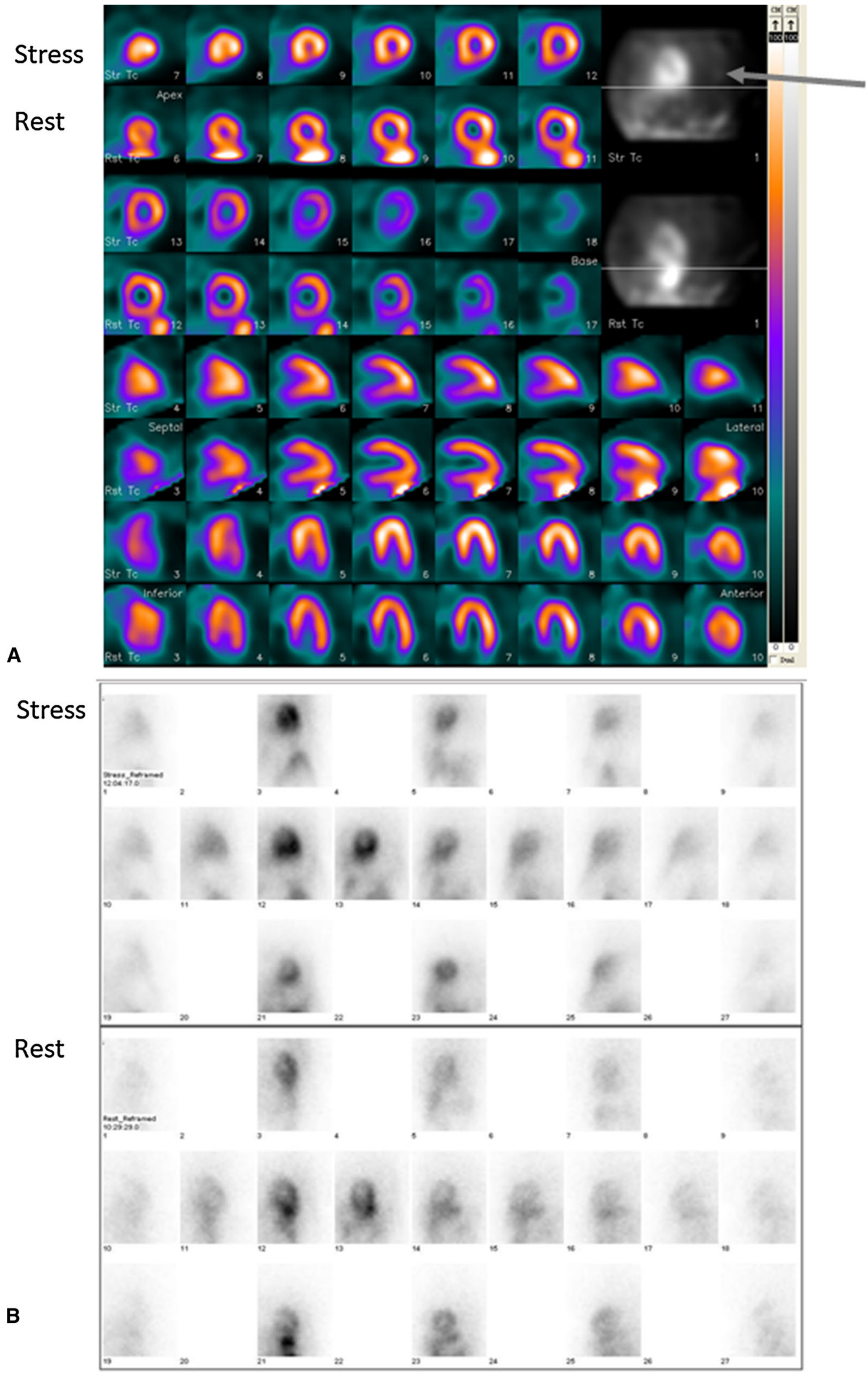
Oddstig presents a comparison of the attenuation patterns between a multi-pinhole SPECT system and conventional SPECT systems.[1] Practitioners using multipinhole CZT cameras will find this article useful because it presents the readers with differences in the patterns of attenuation, helping to familiarize them with differences to be expected, especially for practitioners who do not use attenuation correction routinely.

Figure 1. Oblique reconstruction images and pinhole projection data for a rest-stress Tc-99m tetrofosmin study of a normal female. (**A**) Stress images are inferior in quality to the resting images, with poorer contrast between the myocardium and the ventricular chamber. The shape of stress vertical long axis images is also noted to be oddly pointed. The images on the slice display (gray arrow) are maximum intensity pixel (MIP) projections created from the transaxial slices, not true projection data. The MIP projections are useful for evaluating patient positioning and extra-cardiac activity. (**B**) Inspection of the projection images for the each of the 19 pinholes cameras allow a better evaluation of the study's quality. The heart of a properly positioned patient would be centered in each image. In this example, the patient was slightly too far into the scanner during the acquisition and the heart is in the top half of the frame. Also note that the ventricular chamber is not as distinct on the stress images as the resting images. This is due to patient motion during the scan and is the cause of the abnormal shape of the vertical long axis images. ►

Oddstig presents and compares the different patterns of attenuation between multipinhole CZT camera and conventional SPECT cameras, with and without correction.[1] This one of the first articles in the literature addressing the different attenuation patterns in this variety of cardiac-optimized cameras compared to conventional cameras. The research group specifically looked at the localization, extent and depth of attenuation artifacts in MPI SPECT in patients and phantoms using the two types of cameras.

Attenuation artifacts will occur in images made in multipinhole CZT SPECT systems as well as conventional SPECT systems. Given the differences in configuration of the cameras, crystal materials, acquisition of images are different for these two modalities, attenuation patterns are also different, and therefore attenuation correction images are different too.

Compared to conventional cameras, the authors found that the multi-pinhole system presented slightly less attenuation but covering a larger angular range, extending through the lateral base. This finding was consistent between phantoms and patients and was consistent with the findings of a phantom study by Liu et al.[7] Liu used an anthropomorphic phantom and water bags to simulate soft tissue and breast attenuation. They found that breast attenuation presented fewer artifacts on the multi-pinhole camera. One limitation of the Oddstig's study is that only 5 of the 22 patients were female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so breast attenuation artifacts were not thoroughly investigated.[3]

The differences in attenuation patterns show that when quantitative software is used, normal databases developed for conventional SPECT systems are not suitable for scans done with the multi-pinhole system. System-specific normal databases must be developed.[8] Quantitative software with normal databases developed for the multi-pinhole system has been shown to give quantitative sensitivity comparable to an experienced reader. Adding attenuation correction may help improve the quantitative specificity without loss of sensitivity.[4] Quantitative analysis may be particularly helpful for clinicians making a transition from traditional SPECT to the multi-pinhole system.

Becoming familiar with attenuation patterns as presented by Oddstig is valuable knowledge for the clinician to have. Quantitative data are a useful adjunct in image interpretation. Occasionally, however, the images presented defy a straightforward interpretation. In cases like this, communication with the nuclear technologist who performed the scan, about the patient body habitus and compliance with instructions, is a valuable tool. Most importantly, tomographic images are created from projection images, whether they are acquired on a conventional or multi-pinhole camera. The projection data must be evaluated whenever images are abnormal. The authors of this editorial believe that review of the projection images should be a routine part of SPECT interpretation regardless of the acquisition system.

The projection images for the multi-pinhole system may initially appear foreign for clinicians not used to pinhole collimation. Oddstig notes that pinhole images are subject to parallax where the size of objects in the image is dependent on the distance from the collimator. Given that the detectors are looking at the heart from 19 different angles, the parallax will be present; however, the image reconstruction should resolve for the tomographic images. Review of the projection data can give clues to extra-cardiac activity, attenuation, patient positioning, and even patient motion (Figure 1). With a little experience, there is wealth of information about the scan in the pinhole projections, similar as the information obtained by viewing the planar projections on conventional SPECT.

TAKE HOME MESSAGE

The American Society of Nuclear Cardiology has called for the adoption of advances in stress imaging protocols, camera technology, and processing software that can enhance diagnostic accuracy as well as reduce radiation exposure. The use of high-sensitivity systems such as multi-pinhole SPECT and attenuation compensation are part of these advances.[9] Knowledge about the pattern of attenuation in MPI studies using multi-pinhole CZT gamma cameras is important for practitioners not using attenuation correction, to avoid misinterpretation of images. Quantitative analysis can also be a useful adjunct, as long as system-specific normal files are available. The knowledge presented here must be coupled with review of the raw data (in this case 19 pinhole projections). In the final analysis, there is no substitute for experience in making a clinician proficient with the newly introduced systems such as multi-pinhole CZT SPECT.

Disclosure

There are no disclosures from the authors related to this article.

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