Middle East Journal of Science

https://dergipark.org.tr/mejs

MEJS

e-ISSN:2618-6136

Research Article

INVESTIGATION OF CENTERING PROBLEM IN THE CADMIUM ZINC TELLURIDE (CZT) CARDIAC CAMERA

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Abstract: *Cadmium Zinc Telluride (CZT) Cardiac Cameras are a special SPECT cameras with solid state cadmium zinc telluride detectors. This diagnostic method applied in the evaluation of coronary artery disease is well designed for myocardial perfusion scintigraphy. Aim: CZT cardiac cameras have a limited detector area. In patients who are morbidly obese or whose heart is not in its normal location in the body, the center of the heart and the isocenter of the device do not coincide. It is aimed to investigate how these conditions affect the imaging performance of the CZT cardiac camera. A homogeneous and spherical ball with a diameter of 4 cm was used for the research. To be able to measure away from the center a wooden phantom with 8 cavities and a total length of 32 cm was designed. The center as reference point has been determined by matching the center of the device with the center of the sphere. For the next imaging, the image was taken by placing the spherical ball in the other cavities, respectively, without changing the center. According to the results obtained, farther from the center, deviations from sphericity and differences in dose distribution were observed. Counts decreased by 1.5% in the 2nd position and 16% in the 3rd position relative to the center in the X-axis. A disaster area has been formed and the image area has been exited from the 4th imaging. It is very important to center the patient as much as possible, otherwise the doctor will misdiagnose.*

Keywords: *Cardiac Imaging, (CZT) SPECT, Nuclear Medicine, Centering Problem.*

Received: March 23, 2023 *Accepted: July 25, 2023*

1. Introduction

Nuclear medicine is a branch of science in which diagnostic imaging and treatments are performed with the help of radionuclides given to the body. Radionuclides affect the biochemical and physiological processes of the human body, and the radiation emitted during their disintegration during the steady state is detected by detectors. The detection of radiations emitted by radioactive materials is provided by Single Photon Emission Tomography (SPECT) and Positron Emission Tomography (PET).

Development of the technology of devices used in nuclear medicine imaging; made significant contributions in terms of image quality, imaging time, and patient radiation dose. Studies in SPECT systems in recent years aim to increase system efficiency and image resolution [1]. One of these devices is the new generation of Cadmium Zinc Telluride (CZT) Cardiac Cameras, developed with this goal and started to be used in nuclear cardiology [2-3].

CZT Cardiac Cameras are specialized SPECT cameras with solid state cadmium zinc telluride detectors. It is designed for myocardial perfusion scintigraphy, most commonly used in nuclear cardiac studies. Myocardial perfusion imaging (MPI); it is an examination based on imaging the distribution of blood flow feeding the myocardium by means of an intravenous (IV) radiopharmaceutical. It is a two-stage physiological event; first, the radiopharmaceutical must be able to go to the myocardial tissue, and second, metabolically active myocardial cells must be able to capture this substance. MPI; it is used to identify areas of a patient with relative or absolute decreased myocardial agent associated with coronary artery disease, infarction, ischemia, or scarring [4-6].

Cardiac imaging is a frequently used diagnostic method in obese and morbidly obese individuals. Obesity; it is a risk factor for cardiovascular diseases such as hypertension, coronary artery disease, heart failure and atrial fibrillation. Therefore, cardiac imaging evaluation is very necessary in obese patients. More soft tissue attenuation in obese patients reduces the accuracy of MPI. Research proves that with CZT detectors, the artifacts of SPECT can be reduced and image quality improved. [7]. However, the device's limited detector area is not suitable for patients who are morbidly obese or whose heart is not in its normal position in the body. In these patients, the center of the heart and the isocenter of the device do not coincide. This creates the centering problem. The aim of the present study is to create a centering problem using a phantom in a CZT cardiac camera and to investigate the effect of images obtained outside of centering on image quality.

2. Materials and Methods

2.1. CZT Gamma Camera

It is an alternative detection system to conventional gamma cameras for gamma ray detection and imaging in nuclear medicine. Radiation detection efficiency is high as the solid material in its structure effectively blocks the gamma rays. Unlike conventional gamma cameras with standard [NaI(Tl)] crystals, the CZT detector is a semiconductor with higher count sensitivity that directly converts gamma photon energy into an electrical signal. The device has a C-shaped gantry containing multiple detectors (Fig. 1). It has 19 fixed detectors arranged in 3 rows, oriented perpendicular to the long axis of the patient, each equipped with multipinhole collimators with an aperture diameter of 5.1 mm. Nine detectors are positioned along a transaxial portion and are dispersed around 180°. Other detectors are tilted and positioned in two groups of five detectors on either side of the main detector row. All detectors view the same center of rotation where the heart should be positioned [8-9]. In Figure 2, the center of the CZT detectors and the positions of the balls during imaging to create a centering problem are shown.

2.2. Phantom

A homogeneous and spherical ball with a diameter of 4 cm was used for the research. To be able to measure away from the center; measurements were taken at 4 cm intervals along the X-axis and Z-axis. On the diagonal, measurements were taken at 4x1.41 = 5.6 cm intervals (Fig. 2). There are no spaces between the cavities. A wooden phantom with 8 cavities and a total length of 32 cm was designed. In order to place the spheres on the phantom, the diameter of the cavities in the phantom is equivalent to the diameter of the spherical ball. Tc-99m was used in myocardial perfusion scintigraphy. Tc-99m activity was measured in the Atomlab 500 dose calibrator for injection into the spherical ball.

Figure 1. Cadmium Zinc Telluride (CZT) Cardiac Camera.

2.3. Measurements

5 mCi Tc-99m activity was added into a 0.5 lt water-filled pet bottle and it was shaken for 1 minute and distributed homogeneously. Then the homogeneous mixture was injected into the spherical ball. For the first imaging, the spherical ball was placed in the first recess of the phantom. By matching the center of the device with the center of the sphere; the center, which is our reference point, has been determined. For the next imaging, the image was taken by placing the spherical ball in the other cavities, respectively, without changing the center. A total of 8 images were obtained by moving the spherical ball 4 cm away from the center along the X-axis. A total of 5 images were taken by moving the spherical ball 4 cm away from the center along the Z-axis. A total of 5 images were obtained by moving the spherical ball 5.6 cm from the center along the diagonal axis. Figure 3.a shows the centered imaging where the isocenter of the device and the center of the active sphere coincide, X-1; it represents the active sphere imaging placed in the first slot in an 8-slot board. In Figure 3.b, it is shown how the imaging takes place at a distance of 4 cm from the center (X-2), and in Figure 3.c, at a distance of 12 cm from the center. Images were obtained by placing the active sphere in the 2nd cavity for X-2 imaging, and the active sphere in the 4th cavity for X-4 imaging. Continuing in the same way, imaging in all axes was completed.

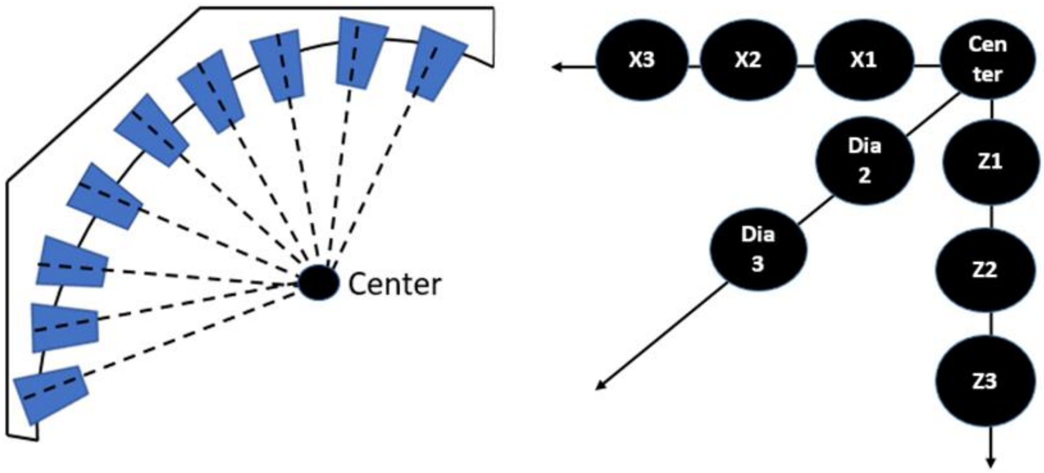
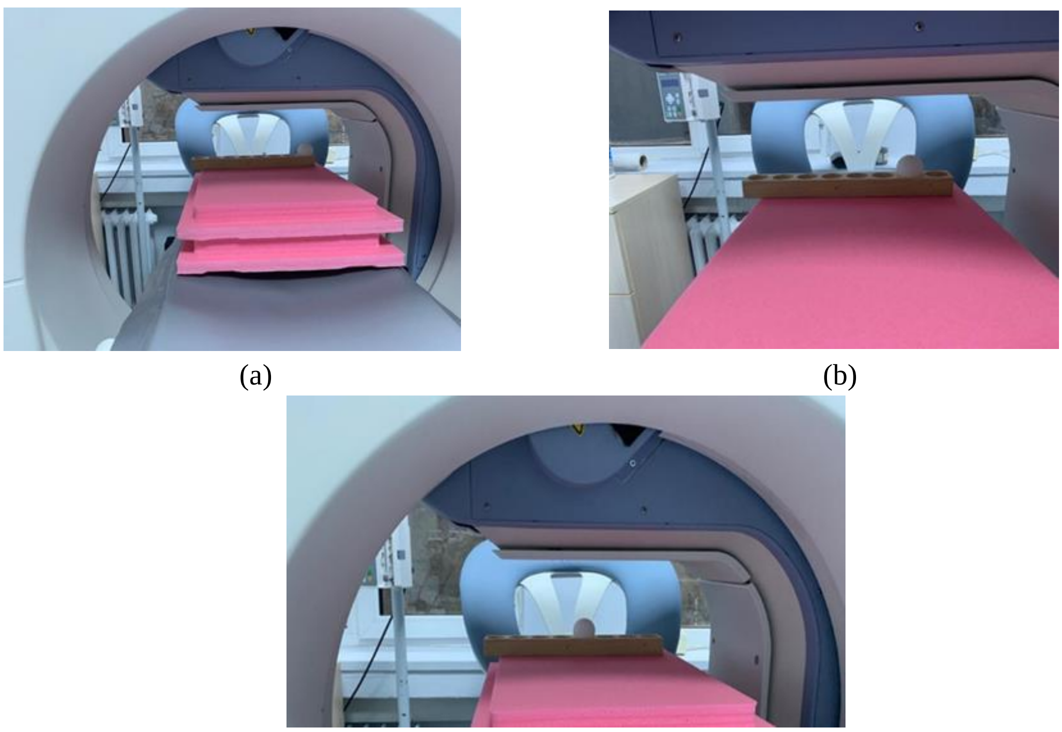


Figure 2. The center of CZT detectors (left), The positions of the balls during imaging to create a centering problem (right).



(a) (b)

(c)

Figure 3. a.) Centered imaging X-1, b.) Example of imaging (off-centre imaging), X-2, c.) Example of imaging (off-centre imaging), X-4.

3. Results and Discussion

In CZT cardiac cameras, whose gantry is smaller than conventional cameras, heart focused collimation is performed by using multipinhole collimators. In the geometry where the multipinhole collimators are fixed and focused on the concentric of the device, the center of the collimators and the center of the heart are overlapped to obtain images with focused imaging capability optimized for the heart. The geometry of the device allows simultaneous detection of counts from all directions without rotating the detectors. The device has high energy resolution and spatial resolution [10]. Due to the high energy resolution, the energy window can be narrower, thus reducing scattering. High quality images are obtained with high spatial resolution. All these innovations significantly reduce imaging time and expose the patient to less radiation compared to conventional SPECT.

While providing positive results supported by studies in the literature for normal patient using CZT cardiac cameras, these results may differ for obese patients. The quality of images obtained in nuclear medicine imaging is of great importance for the correct diagnosis of patients. CZT imaging can be performed in patients with normal weight (BMI: 18.5-24.9 kg/m^2) and overweight (BMI: 25-29.9kg/m^2). But, in obese (BMI: 30-40 kg/m^2) and morbidly obese (BMI $\geq$ 40 kg/m^2) patients, it cannot be performed correctly because the detector cannot get close enough to the patient due to the limited detector area.

In a study comparing conventional SPECT and CZT-SPECT for myocardial perfusion imaging, the total radiation doses received by the patients matched according to gender, age and body mass index were compared. While it was determined that the patients received lower radiation doses in the imaging performed with CZT-SPECT, it was observed that the obese patients among the comparison patients received a higher radiation dose than the normal-weight patients [11].

In the study of Michael et al. [12], image quality analysis was performed for 63 patients in a similar study in which myocardial perfusion scintigraphy was evaluated in CZT SPECT in patients with high, very high, and excessive body mass index. The image quality assessment was based on predefined cardiac image features and radioactivity uptake. SPECT images of the same patients were also evaluated for comparison. According to the results obtained, it was concluded that SPECT should be planned because it is difficult to obtain diagnostic image quality in CZT in patients with a body mass index of 40 kg/m^2 and above. The present study is a phantom study, and it allows the evaluation of image quality by including count and volume information according to the distance from the center. Our results also show parallels to the results of Michael et al. Since there is a possibility that the hearts of patients with a BMI index above 40 kg/m^2 may go out of the Field of View (FOV) of the CZT cardiac cameras, it is recommended that these patients be included in SPECT.

The spherical ball used in the present study has a volume of 33.4 cm^3. While obtaining the image of the spherical ball in the center, the threshold value corresponding to 33.4 cm^3 volume was determined. This value is 24%. While obtaining data from other images, a threshold was determined as 24% and all results were obtained using this value. When the results are evaluated; for all 3 plans, count values decreased as they moved away from the center and deviations from sphericity were observed. This variation is more pronounced in the X and diagonal axis measurements, as we expected. Counts decreased by 1.5% in the 2nd position and 16% in the 3rd position compared to the center in the X-axis. Counts decreased by 3.9% in the 2nd position and 21.7% in the 3rd position compared to the center in the diagonal axis. Counts decreased by 9.9% in the 2nd position and 11.9% in the 3rd position compared to the center in the Z-axis. For each axis, a disaster area was formed from the 4th image. Thus, the imaging was stopped and the image area was moved out. The results obtained were evaluated in the axial, coronal, and sagittal planes. And results are given in Fig. 4, Fig. 5, and Fig. 6.

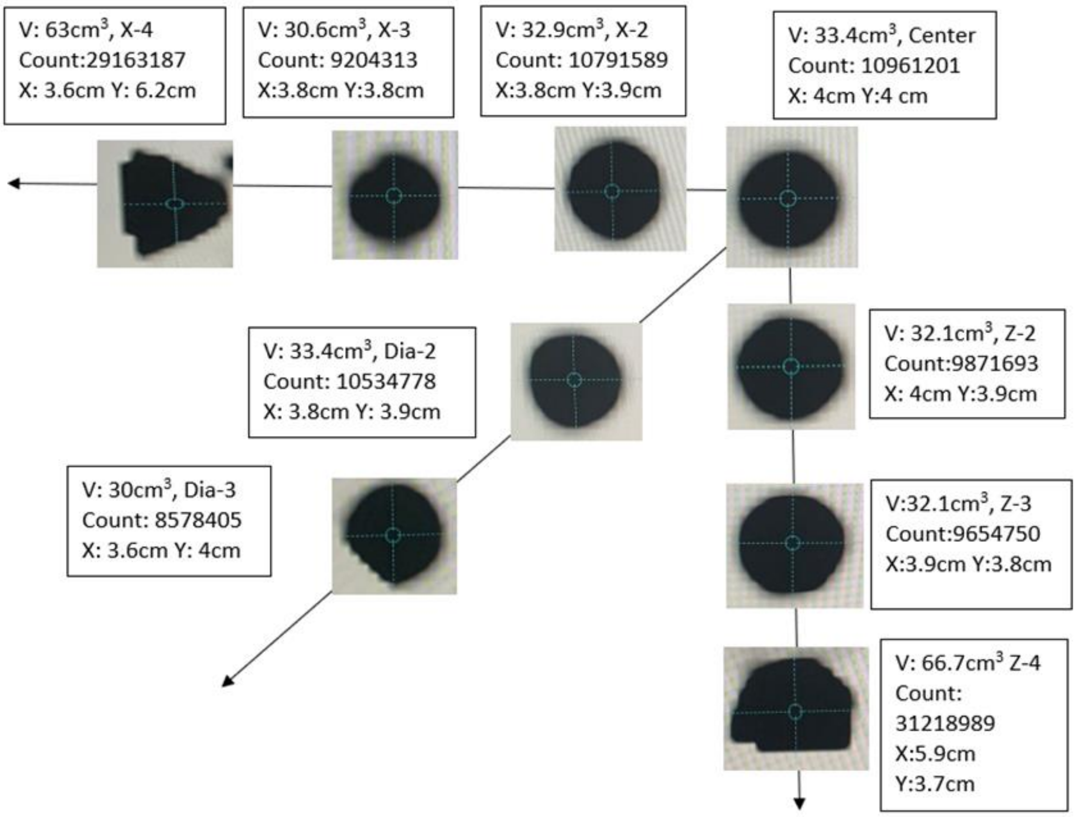


Figure 4. Images taken in axial plane and measurement results.

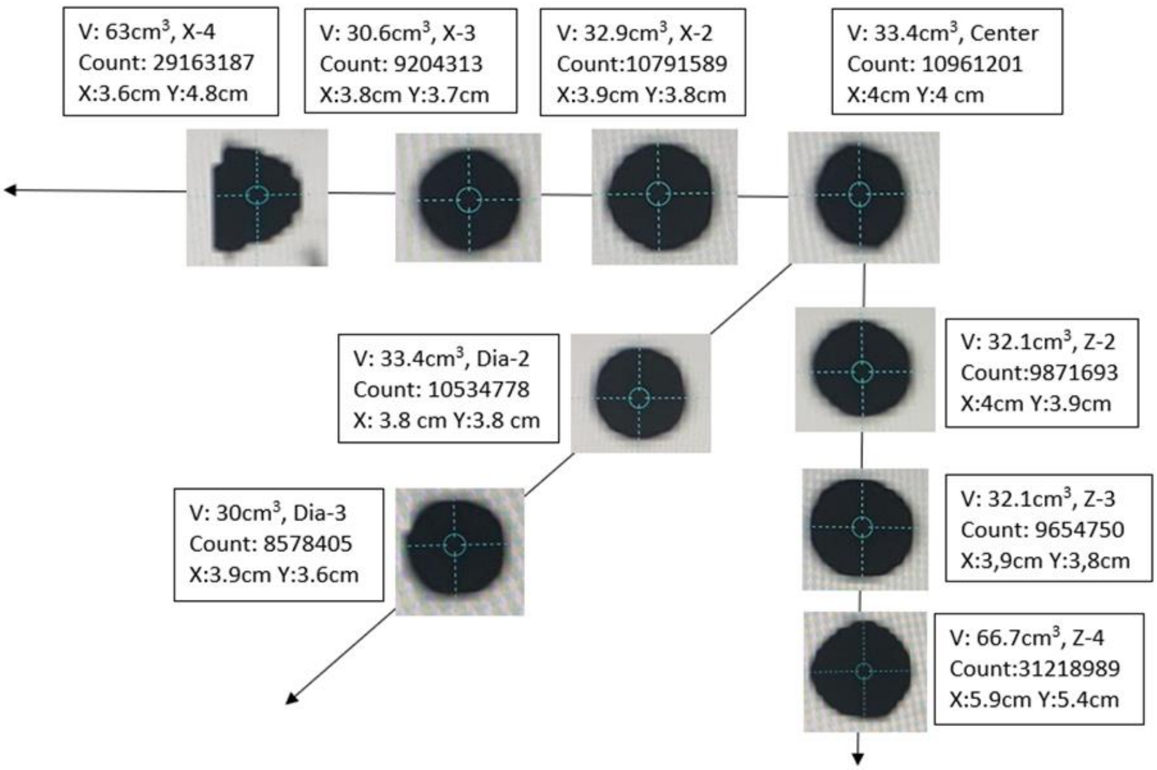


Figure 5. Images taken in the coronal plane and measurement results.

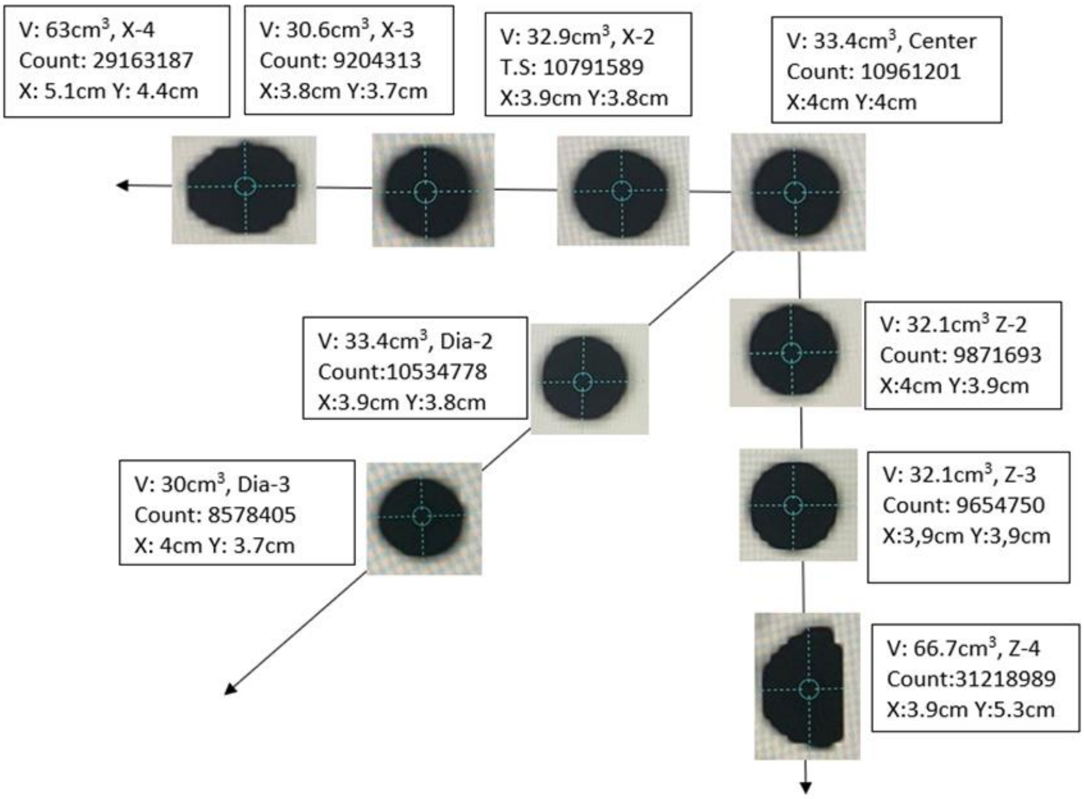


Figure 6. Images taken in the sagittal plane and measurement results.

If we clinically evaluate the count loss in imaging from outside the center; myocardial ischemia can be interpreted as infarction. This causes an incorrect perfusion defect. As there is a change in the dimensions of the sphere as it moves away from the center for all axes, the total volume also changes. Compared to the 3rd imaging made on the central volume axes; It decreased 8.4% for the X-axis, 3.9% for the Z-axis and 10.2% for the diagonal axis.

In a similar study in which MPI imaging was performed on CZT camera in 18 patients; after first obtaining an image with the heart positioned in the center of the quality field of view (QFOV), the patients were re-imaged at different positions 5-20 mm from the center. Examined positions; moving the camera 5, 10 and 20 mm away from the patient, lowering the table 20 mm and moving the table inward 20 mm. When the acquired images were evaluated, a count loss was observed for all off-center images tested, as in our study [13]. The study provides information on images up to 2 cm off center. Considering the patients with a limited 18 cm area of the FOV field and where centering cannot be performed, it is important to know how far off-center the image is obtained and what the results are. The present study provides information on images from 8 cm from the center for the X and Z axes and 11.2 cm from the center for the diagonal axis.

For centered and off-center imaging along the X axis, the variation in counts of the spheres along the diameter was investigated. Dose profiles were given in Fig. 7, Fig. 8 and Fig. 9. As shown in Figures 7, 8, and 9, when we look at the change in count along the diameter of the spherical ball according to the distance from the center, the count difference increases as the distance from the center increases and the homogeneity deteriorates. When we compare the count reductions in the centers of the spherical balls, they decreased by 31.8% for X-1 imaging, 34.8% for X-2 imaging and 47.85% for X-3 imaging. This is due to decreased counting efficiency and self attenuation of balls. While less collapse is observed in the center compared to the edges in X-1 imaging, collapse is more in X-2 and X-3 imaging. This effect is significant as attenuation correction is not performed using CT on the CZT cardiac camera device. Especially if imaging is done for X-3 position and after, a uniform distribution may appear quite distorted. This causes misinterpretation.

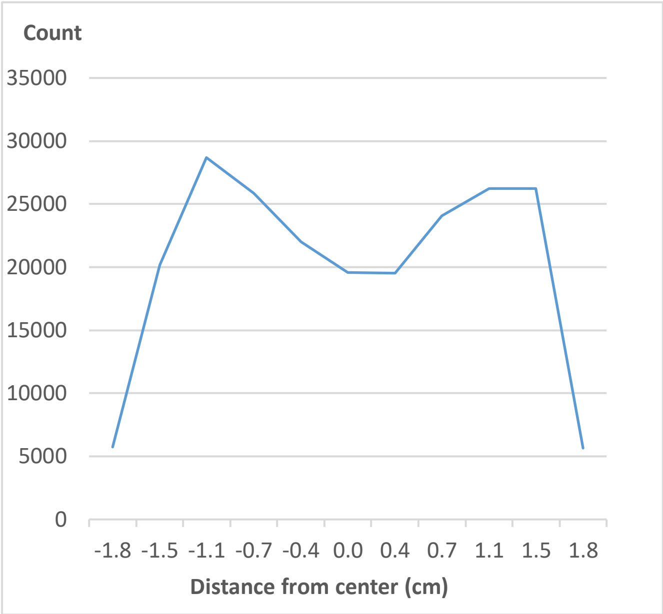


Figure 7. Count variation along the diameter of the centered sphere, X-1.

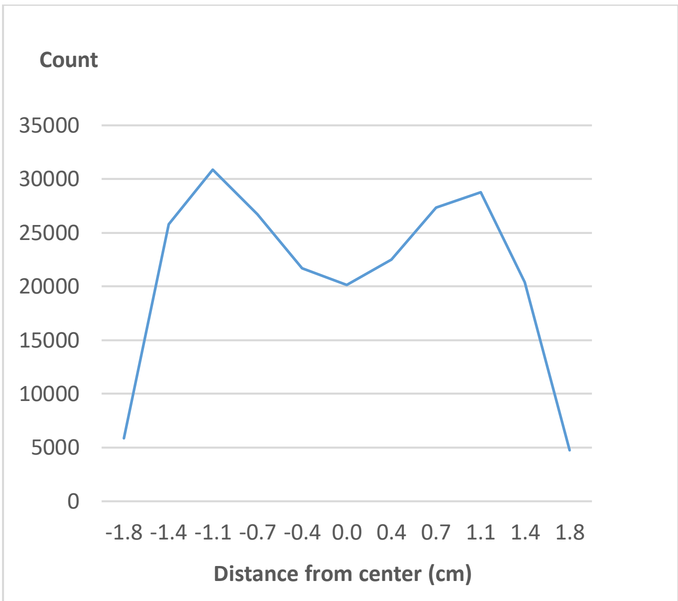


Figure 8. Count variation along the diameter of the sphere 4 cm from the center, X-2.

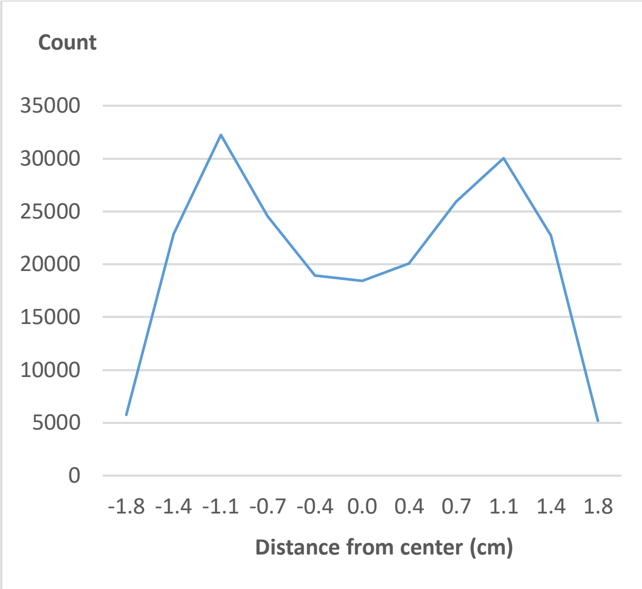


Figure 9. Count variation along the diameter of the sphere 8 cm from the center, X-3.

4. Conclusion

According to the phantom results obtained from a 4 cm diameter ball filled Tc-99m; the farther from the center of the ball, the counting efficiency decreases, the shape changes (such as narrowing or widening of the axes, decrease in the volume) and deterioration of the homogeneous distribution have emerged. Interpretation of images obtained in this way may lead to misdiagnosis and thus affect the patient's treatment. It is of utmost importance to always ensure optimal patient positioning. Since centering cannot be performed in patients who are morbidly obese, have a wide chest wall and large breast structure, and whose hearts are not in their normal positions in the body, it is recommended to perform heart extractions using a conventional SPECT device.

Ethical Statement:

Our study does not cause any harm to the environment and does not involve the use of animal or human subjects. Therefore, it was not necessary to obtain an Ethics Committee Report.

Conflict of İnterest:

The authors must notify of any conflicts of interest.

Authors' Contributions:

E.M: Writing - Original Draft Preparation, Investigation, Conceptualization, Data Collection and Processing, Resources (%40).

B.K: Formal Analysis, Methodology, Resources (%20).

E.I: Methodology, Critical Review (%10).

B.D: Formal Analysis, Methodology, Critical Review, Comment (%20).

S.K: Critical Review, Comment (%10).

All authors read and approved the final manuscript.

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