Technical Note

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Introducing a Dedicated Cardiac SPECT Imaging System: ProSPECT

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Abstract

Purpose: Cardiac SPECT imaging is widely used for many clinical practices such as the diagnostic of coronary artery diseases (CAD) and Myocardial Perfusion Imaging (MPI). In this work, we introduced the ProSPECT system, a dedicated cardiac SPECT system with open-gantry design.

Materials and Methods: In this study we assessed the performance of the system based on NEMA-NU1-2007 standards. The ProSPECT system was characterized by measurement of planar, tomographic and clinical parameters.

Results: Planar measurements showed 7.6 mm and 8.9% of spatial resolution and energy resolution at 140 keV, respectively. The tomographic resolution at 250 mm radius of rotation was 12.3 mm. Also, the maximum LOR and COR error for the tomographic imaging are obtained 1.1 mm and 1.8 mm, respectively. The clinical images that obtained using the system were confirmed by nuclear medicine physician expert.

Conclusion: It concluded that the ProSPECT imaging is qualified for cardiac SPECT imaging.

1. Introduction

Since the heart diseases are the most common cause of death in the most countries of the world, the diagnostic of Coronary Artery Disorders (CADs) and Myocardial Perfusion Imaging (MPI) have always been a concern [1]. One of the powerful tools that widely used for diagnostic the cardiovascular diseases in recent years is cardiac Single Photon Emission Computed Tomography (SPECT) imaging [2-4]. The cardiac SPECT system typically has two scintillation detectors equipped with parallel-hole collimators in a fixed 90° angle that rotate around a patient's body from the Left Posterior Oblique (LPO) to a Right Anterior Oblique (RAO) in the supine position. There are some fundamental limitations in these systems such as long scanning time, poor image quality, low image resolution and patients dose. Also, the images suffer from some artifacts including motion artifact, diaphragmatic attenuation, extra cardiac activity, breast attenuation and so on [5]. In recent years, many researches have been performed in detection technology, mechanical design and reconstruction algorithm in the systems to improve image quality and diagnostic accuracy [6, 7].

The most common position for the cardiac SPECT imaging is supine but it suffers from artifacts of the anterior wall, apex and inferior wall [8-10]. Imaging in the prone position prevents the attenuation artifacts from the diaphragm by lowering of the diaphragm and sub diaphragmatic organs. So the prone imaging introduces higher specificity and accuracy for diagnosis coronary

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artery disease [11-17]. Since the prone imaging also has caused some drawbacks, including increasing camera-to-chest distance and artefactual anteroseptal defects [12, 18], combination of supine/prone imaging especially can be used to evaluate positional artifacts and to improve overall accuracy for the diagnosis of CAD [9, 10, 15, 18, 19].

In other words, the well-designed and optimized equipment to acquire clinical data and rotate the detector around the patient body in 360 arc can provide all scan protocols (both supine and prone imaging), accurate and high-quality imaging. The proper design of the instrumentation can improve the patient handling, imaging protocol and diagnostic accuracy [6, 20]. In this study we introduce our dedicated cardiac SPECT imaging system (called ProSPECT) and then evaluate the performance of this system in planar, tomographic phantom study modes. The planar assessment also was presented in previous work in more details [21] and in this study was indicated briefly.

2. Materials and Methods

The ProSPECT system is introduced as an optimized and low-cost design in nuclear cardiology (Figure 1). The gantry and table of the system are designed to comfortably accommodate patients and to provide dual patients positioning (supine and prone). The ProSPECT system can scan a variety of patients with all shapes and sizes because of a 76 cm bore of the gantry. The system also provides a wide range of SPECT scans such as supine, prone, dextra-cardia, 180 degrees and 360 degrees arc. Because of decreasing radius of rotation till 21 cm, the ProSPECT system can be applied for brain scan too.

The ProSPECT system is equipped with two detectors with small FOV to minimize extra cardiac activity. A combination of a large field NaI(Tl) crystal with 40×25 cm^2 area and 9.5 mm thickness and an array of 6×4 square PMT with 76×76 mm^2 area used as detection system. More information about the detector presented in our previous work [21].

The performance of the ProSPECT system in planar, SPECT and tomographic states is evaluated according to the NEMA (National Electrical Manufacturers Association) standard with number of NU-1:2007 regarding to gamma camera [22].

Figure 1. The ProSPECT system

2.1.Planar Evaluation

All the planar evaluations, such as linearity, uniformity and sensitivity, were performed according to the NEMA. Also the intrinsic and extrinsic spatial resolution with and without collimator, respectively, was measured and reported. Note that a LEHR (Low Energy High Resolution) collimator was used in both the extrinsic spatial resolution test and sensitivity test [21].

2.2.Tomographic Evaluation

We followed the NEMA procedures for the tomographic assessment of the ProPSECT system. Thus the system alignment and also tomographic spatial resolution was measured [22]. The system alignment is reported as COR (Centre of Rotation) and axial alignment errors. Also the reconstructed spatial resolution with and without scatter environment in three different axis X, Y and Z was calculated.

2.3.Phantom Study

A dedicated phantom was designed and fabricated from the combination of Polyethylene and Plexiglas to simulate the human heart as shown in Figure 2. Also a separable defect with dimension 25×20 mm^2 and 5 mm thickness is constructed that until the heart phantom can be used with and without the defect.

Figure 2. An in-house heart phantom to assessing image quality of the ProSPECT system

The phantom was filled uniformly with 500 uCi Tc-^{99m} dissolved in normal saline to acquire the image. Then the phantom in both supine and prone mode of scan with routine acquisition parameter including 90 arc scan, 16 numbers of views, 25 sec time per view and dual head mode. Also the two acquired images were reconstructed using the MLEM method with 6 iterations and 4 subsets and with Butterworth post filtering (10 orders, 0.37 cut-off frequency).

3. Results

The planar and tomographic specifications were summarized in Table 1. Also the two acquired images from heart phantom in supine and prone modes with the defect are presented in amount is competitive to the similar SPECT system.

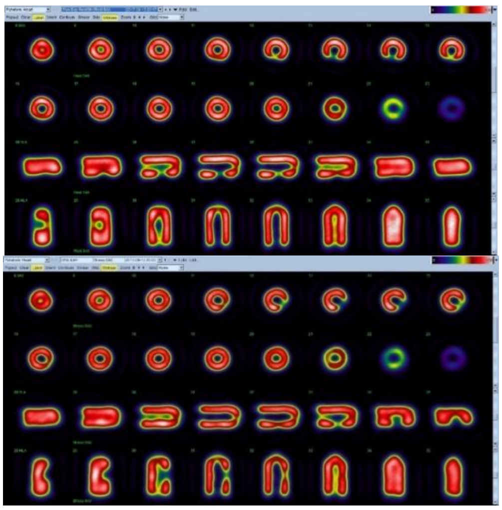

Figure 3. The heart phantom images with defect that are acquired using the ProSPECT system in (Up) supine and (Down) prone modes.

Also the two acquired images from heart phantom in supine and prone modes with the defect are presented in Figure 3.

Table 1. The planar and tomographic specification of the ProSPECT system

Planar Specifications	
Intrinsic spatial resolution	
FWHM in UFOV	≤ 3.5 mm
FWTM in UFOV	≤ 7.4 mm
Intrinsic spatial linearity	
Absolute in UFOV	≤ 0.8 mm
Differential in UFOV	≤ 0.2 mm
Intrinsic spatial resolution	
in UFOV*	9.3 %
Intrinsic flood field uniformity	
Integral in UFOV	≤ 2.2 %
Differential in UFOV	≤ 1.2 %
System spatial resolution w/o scatter at 10 cm	
LEHR	≤ 7.6 mm
Sensitivity	
LEHR	175 cpm/µCi
Tomographic Specifications	
Tomographic spatial resolution w/o scatter at ROR†=200mm	
Tangential	≤ 7.8 mm
Central	≤ 9.5 mm
Radial	≤ 9.5 mm
System Alignment at ROR=200mm	
COR errors	≤ 2.5 mm
Axial error	≤ 1.5 mm

*Useful Field of View
†Radius of Rotation

4. Discussion

The presented results in Table 1. Also the two acquired images from heart phantom in supine and prone modes with the defect are presented showed that all of the specification of the ProSPECT system is comparable and competitive to other commercial SPECT imaging systems. Also the heart phantom imaged (shown in Figure 3.) indicated that the ProSPECT system introduced good quality and excellent resolution in cardiac imaging in both supine and prone modes.

5. Conclusion

The ProSPECT system, a dual-head SPECT system, was designed, developed and optimized for high resolution imaging of human cardiac. The aim of this study was introducing and also evaluating the performance of the system.

All of the presented results indicated that the system is adequate for diagnosing Cardiac Artery Disease (CAD). Note that the system can cover a variety of patients with different weight and height (150 kg, 210 cm) and also can provide a variety of scan such as 180, 360, supine and prone and also some non-cardiac imaging such as brain and thyroid scan. Also the system is a low weight system (total weight of the system is only 900 kg) because of using the small detector of the system that optimized for cardiac imaging. Further clinical evaluations of the ProSPECT in Myocardial Perfusion Imaging (MPI) are necessary and currently under study.

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