Experimental Evaluation of the Performance of HiReSPECT Scanner: a High-Resolution SPECT System for Small Animal Imaging

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ABSTRACT

Purpose: In this report, the preliminary results of the experimental evaluation of the Performance of HiReSPECT scanner have been illustrated.

Methods: In order to assess the capability of the scanner in both planar and tomographic modes, three rats were injected with ^{99m}Tc, ^{99m}Tc-DMSA, and ^{99m}Tc-MDP for thyroid scan, kidney scan and bone scan respectively in order to perform planar imaging. In addition, two rats were injected with ^{99m}Tc-MIBI and 99mTc-DMSA to perform cardiac and kidney tomographic imaging, respectively.

Results: Tomographic and planar scans of the rat organs showed that radioactive distribution in cardiac, kidney, bone and thyroid images exhibited detailed physiologic information of the imaged organs. Due to high resolution performance of the scanner, thyroid lobes are well depicted and distinguished from each other.

Conclusion: Results of the evaluation of the planar and tomographic images indicated that HiReSPECT has appropriate imaging capability as an imaging system in biomedical research.

1. Introduction

Advancement in small animal imaging systems plays an important role in the development of biomedical researches [1, 2]. These imaging systems may provide valuable information about physiological and pathological processes inside small animal bodies in the scales down to cellular and molecular levels [3, 4]. One of the imaging modalities used for small animal studies is animal SPECT which provides high resolution images of distribution of radionuclide inside the small animals [1, 3-5]. Imaging of the distribution of the radio-labeled agents in anesthetized animals using animal SPECT scanner, in comparison to postmortem studies, has a significant advantage; there is no need to sacrifice the animals. Functional imaging of small animals by animal SPECT allows performing longitudinal studies in order to monitor a physiological or pathological process and/or assess effects of drugs [6-10]. The successful performance of animal SPECT systems is largely based on the advances in the development of high sensitive gamma detectors to visualize small animal organs with high spatial resolution.

In order to assess practical capability of an animal SPECT scanner, it is necessary to evaluate preclinical values of images obtained by that system in a real con-

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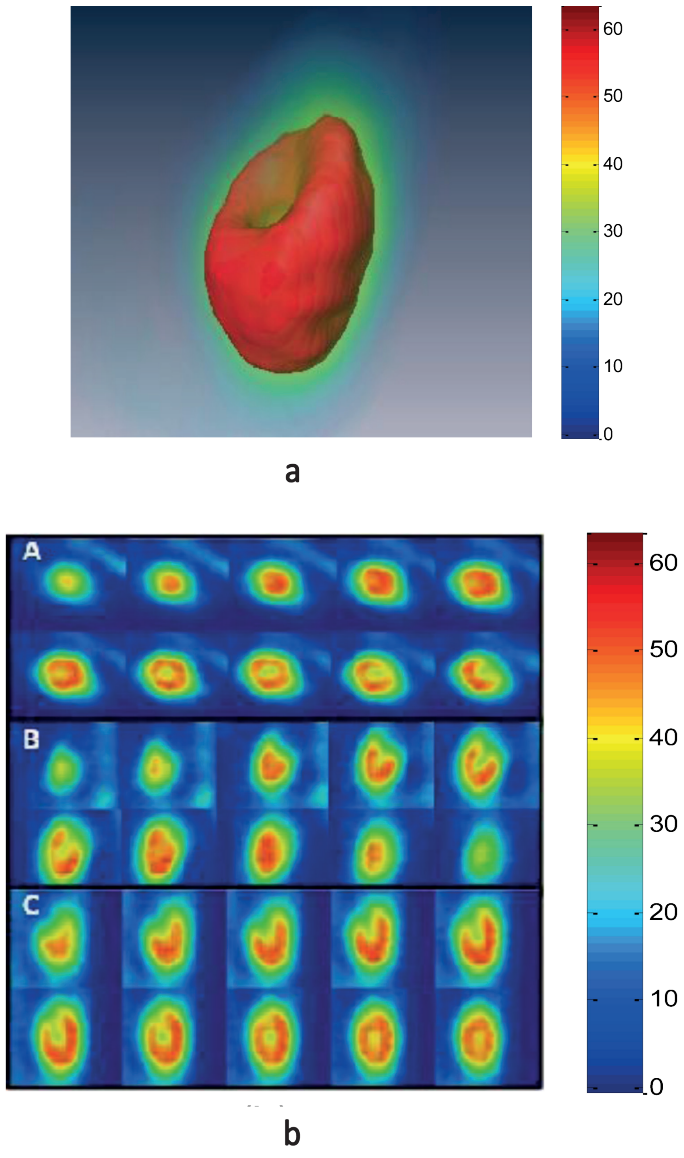

Figure 1. (a) The 3D image of a rat cardiac scan with HiReSPECT system. (b) Axial, coronal and sagittal images of the cardiac scan.

text. Therefore, the aim of current report is to present the first preclinical images acquired with the high resolution animal SPECT scanner called HiReSPECT (Parto Negar Persia Co. Tehran, Iran) which was recently installed in our department.

2. Methods

2.1. HiReSPECT Description

HiReSPECT is a preclinical dedicated SPECT scanner with two heads positioned at 180 degrees angular distance from each other. Each head consists of pixelated scintillator crystal tightly attached to two H8500 position sensitive PMTs (PSPMT) which provides an active detection area of about 50×100 mm^2. The crystal consists of an array of 80×38 pixels (pixel size of 1×1 mm^2) enclosed in 50 µm-thick aluminum and also a 3mm-thick glass window. Each head is equipped with a high resolution parallel-hole collimator (1.2 mm hexagonal holes, 18 mm thickness and 0.2 mm septal thickness) with an active collimating area of 108×56 mm^2 [11, 12]. The sensitivity of the system is about 1.3 cps/µCi and the spatial resolution is 1.7 mm in the planar mode and about 1.6 mm in the tomographic mode [13].

Depending on the type of the animal, rat or mouse, the distance between the heads can be changed by adjusting

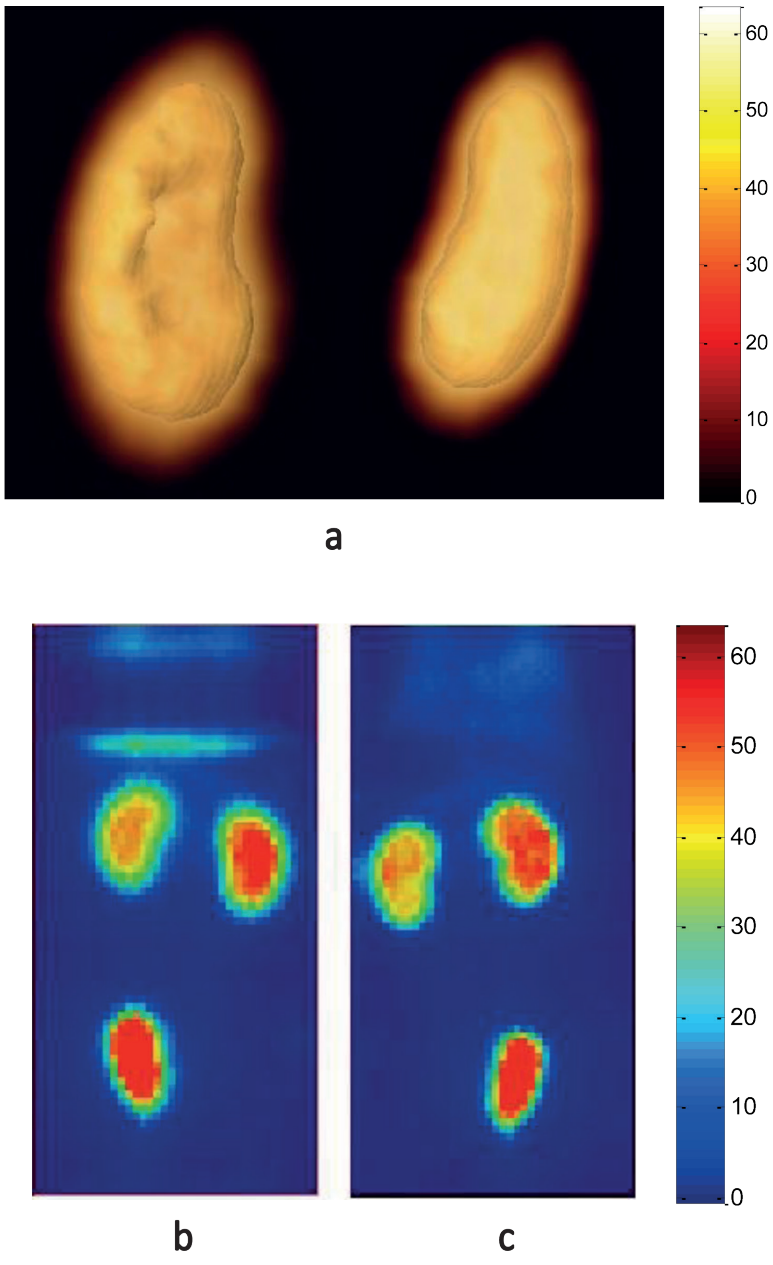

Figure 2. (a) A 3D image of rat's kidneys. (b) and (d) planar image of rat's kidneys in head 1 and 2.

the radius of rotation (ROR). Furthermore, there is an option to rotate each head 90 degrees to provide a larger transaxial dimension with a smaller axial dimension.

The SPECT data acquisition was performed with rotating detectors around the object to be imaged and several projection images recorded. Volumetric images of radionuclide concentrations are reconstructed from these projections. The images are reconstructed using the dedicated HiReSPECT's reconstruction software, 3D Maximum-Likelihood Expectation Maximization (MLEM) [14]. Quantification of the activity accumulated in volumes of interest and regions of interest (ROI), respectively, was performed with Amira® 5.2 processing tools.

2.2. Animal Imaging

Animal imaging was performed with HiReSPECT system where the animals were placed in supine position in the animal bed. All radiopharmaceuticals were injected via the tail vein.

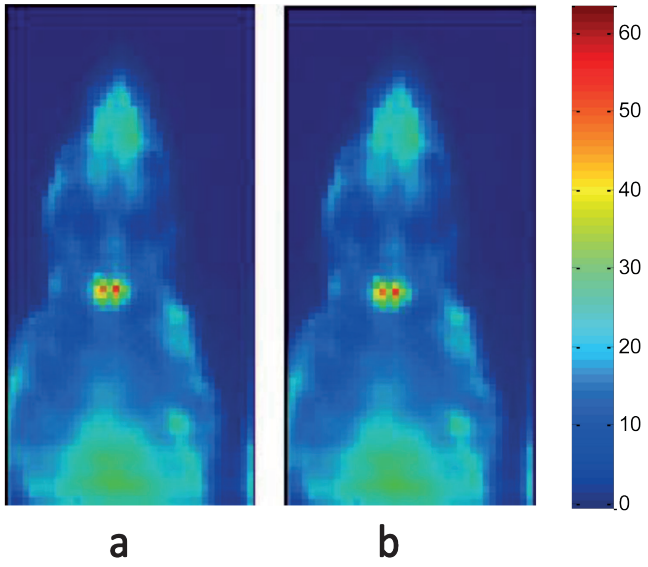

Figure 3. (a) and (b) indicates planar images of thyroid scan for head 1 and head 2, respectively. The images show that the HiReSPECT system is able to distinguish clearly the left and right lobes of thyroid.

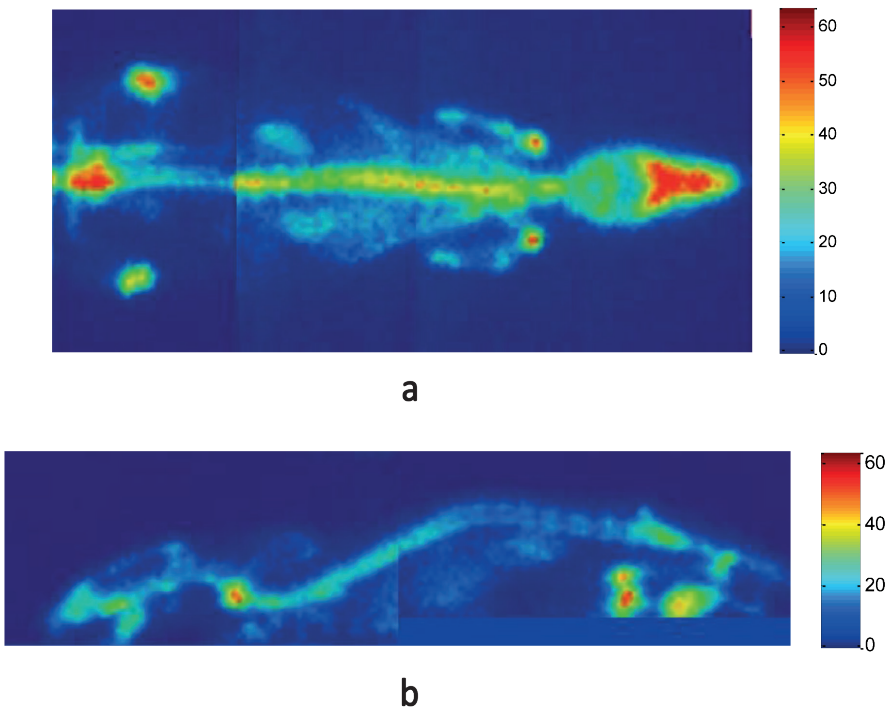

Figure 4. The images of the bone scan of a rat in coronal (a) and sagittal (b) views.

2.2.1. Rat Cardiac Scan

Rat cardiac scan was performed with a male rat (a weight of about 350 grams). The rat was injected via tail vein with 2 mCi of ^{99m}Tc-MIBI (methoxyisobutyl isonitrile). For cardiac scan, about 2 hours after the injection of the radiotracer, the animal was anesthetized with Ketamine/xylazinethen and, then, imaged for about an hour. Configuration of the scanner was set for rat imaging. The projections collected at 6º increments over 180º for

each head and the SPECT data acquisition time was set to 60 seconds for each projection.

2.2.2. Rat Kidney Scan

Planar and tomographic imaging of rat kidneys was performed with 1.2 mCi of ^{99m}Tc-DMSA (Dimercaptosuccinic acid). The rat with a weight of about 320 grams was administrated via tail vein. The animal was anesthetized with Ketamine/xylazinethen about 3 hours after the injection of the radiotracer. In order to perform tomographic scan, the configuration of the scanner was set for rat imaging. The projections collected at 6º increments over 180º for each head and the SPECT data acquisition time was set to 40 seconds for each projection. Planar images of rat's kidneys were done with dual head configuration where the heads were placed at the back and front of the animal and the data were acquired for 10 minutes.

2.2.3. Rat Thyroid Scan

Planar images of rat (a weight of about 350 grams) thyroid were acquired after the injection of 1 mCi ^{99m}Tc. For thyroid scan, animals were anesthetized with Ketamine/xylazineabout 30 minutes after the injection of the radiotracer to initiate imaging. Planar images of rat's thyroid were done with a dual head configuration where heads were placed at the back and front of the animal and the data were acquired for 15 minutes.

2.2.4. Rat Bone Scan

The planar scan was performed for a rat's bone. A rat with the weight of about 370 grams was injected with 3 mCi of ^{99m}Tc-MDP (Methylene diphosphonate). For the bone scan, animals were anesthetized with Ketamine/xylazineabout 30 minutes after the injection of the radiotracer to initiate imaging. Data acquisition time for the bone scan was set on 15 minutes.

3. Results

Fig. 1a Shows the 3D reconstructed image of a rat cardiac scan with HiReSPECT system. This image indicates that spatial resolution of the HiReSPECT system is good enough for cardiac imaging because the cavity of a rat's heart can be observed clearly. Fig. 1b demonstrates a detailed distribution of the activity in axial, coronal and sagittal planes of the cardiac scan.

Fig. 2 shows the reconstructed images of the kidney scan. Fig. 3 illustrated the planar images of thyroid scan for both detectors (heads). The images show that the HiReSPECT system has enough potential to distinguish clearly the left and right lobes of thyroid.

Fig. 4 demonstrates the images of the bone scan of a rat in coronal and sagittal views. The images show the spine, hips and hinge of the bones.

4. Discussion

The increase in the number of researches in the field of biomedicine have not only provided opportunities for the application of imaging systems to study small animals, but also have led to developments in the instrumentation of such imaging techniques [15,16,1,4,11]. Small animal SPECT, as one of these successful techniques which is widely used in biomedical researches, permits a non-invasive study of small animals over time to monitor a physiological process. It also evaluates the efficacy of therapy and consequence assessment of a genetic manipulation [6-10].

In this report, we assessed the capability of the HiReSPECT scanner installed recently in our research center for imaging from rats. Spatial resolution is one of the key factors determining the quality of planar or tomographic scans which gains even more importance when small organs are going to be imaged. For such organs, high quality images with high spatial resolution are needed to provide good preclinical information. Based on the reports of the interpretation of the scan of thyroid, as one of the smallest organs of rats, thyroid lobes are well depicted and distinguished from each other in the reconstructed images. All planar and tomographic scans are well interpretable containing useful preclinical information as a result of high resolution imaging of radioactivity distribution.

5. Conclusion

The experimental evaluation of HiReSPECT dedicated scanner in different rat's organ showed the scanner has enough potential to be used for preclinical researches with good image quality. The spatial resolution and sensitivity of scanner was in a range of other commercially available systems. Further performance assessment with mice imaging is mandatory and we plan to accomplish it in the near future.

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