Development of Dual Modality MRI and SPECT for Pre-Clinical Molecular Imaging

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Purpose:

We are developing an MR-compatible SPECT camera. The SPECT camera system can be inserted into the bore of a state-of-the-art MRI system and allows researchers to acquire tomographic images from a mouse in-vivo with the MRI and the SPECT acquiring simultaneously. The SPECT system provides functional information, while MRI provides anatomical information. The purpose of this work is to demonstrate the feasibility of simultaneous acquisition with both modalities. Our objective is to provide researchers with an instrument that allows one to acquire combined SPECT/MRI images simultaneously. We have previously shown the MR compatibility of CZT based single photon detectors and associated nuclear data acquisition electronics [1]. For the work reported here we assembled a prototype SPECT camera system with a multi-pinhole nuclear radiation collimator. We have acquired MRI and SPECT images from resolution phantoms and a mouse using the SPECT outside and inside the MRI.

Methods:

Figure 1 (left) shows a drawing of the combined SPECT/MRI system with the SPECT camera located inside a small animal MRI system with a 12-cm bore. Figure 1 (center) shows the SPECT camera in a cradle. The camera is 120-mm long and its outer diameter is 119 mm including the cover (not shown). The camera is comprised of 32 digital radiation detector modules arranged in four octagons. A multi-pinhole radiation collimator sleeve is located inside the camera providing a 25-mm field-of-view for the imaging of mice. The key technologies for MR-compatible SPECT include: radiation detectors based on semiconductor crystals (CZT) and application specific integrated circuits (ASICs) which can operate inside the MRI system. We used a multi-pinhole radiation collimator, which allows us to acquire tomographic images from mice without rotating the detectors – a feature which is important for simultaneous SPECT/MRI and interesting for dynamic SPECT applications. Figure 1 (right) shows a photograph of the experimental setup with the SPECT system on the patient bed of a 3-T MRI system before insertion into the MRI bore.

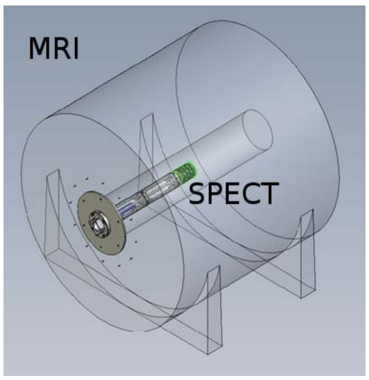

Figure 1 (left): SPECT camera inside an MRI bore.

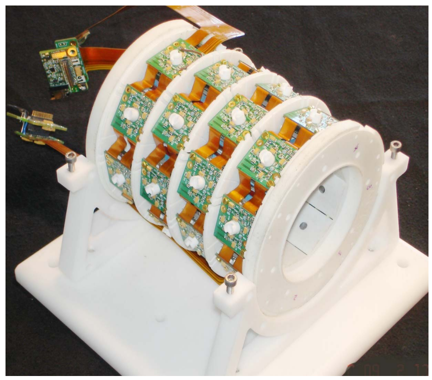

Figure 1 (center): SPECT camera.

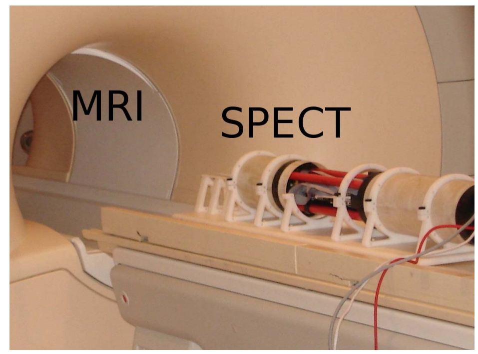

Figure 1 (right): Experimental setup for SPECT/MRI.

Results:

Figure 2 (left) shows the SPECT sagittal image from a healthy mouse in-vivo. The mouse weighed 23.5 g and was 8.1 cm long. Prior to the acquisition, the mouse received 200 micro liter of 99m-Tc-MDP (methyllene-diphosphonate, a bone-seeking ligand) with an activity of 510 micro-Curie. We acquired the mouse SPECT data at earth's magnetic field, using only 24 pinholes (angular samples) in the SPECT system. The mouse was fixed to its bed inside the collimator. We moved the bed 5 times in axial direction to acquire 5 data sets that cover the entire mouse. The reconstructed tomographic image shows the mouse' spine, its skull and the hips as well as the bladder. The image has been acquired using a collimator with 2-mm diameter pinholes. Figure 2 (right) shows the MR sagittal image slice from a mouse located inside the SPECT system during MR acquisition. One can recognize the mouse head, its body and the lungs. Or preliminary results show that the SPECT system minimally affects the MRI.

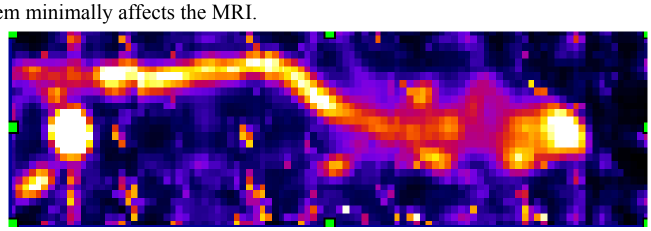

Figure 2 (left): SPECT image of a mouse, still outside of the MRI.

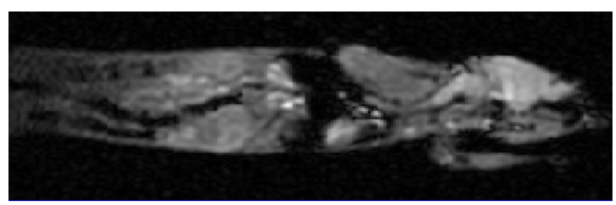

Figure 2 (right): 3-T MRI mouse image – with mouse inside SPECT system.

Discussion:

The SPECT mouse image [Fig.2 (left)] was acquired outside the MRI. Yet, previous tests of the SPECT inside the MRI using phantoms were successful [2]. The MRI phantom results obtained, show that the SPECT system is MR-compatible and allows one to acquire MR images while the SPECT system is taking data. For this work on mice, we started testing the SPECT system with a human MRI system for reasons of convenience and availability. The SPECT mouse image contains artifacts that are mainly due to the small number of angular samples of only 24. The possibilities to improve SPECT image performance include higher spatial resolution through smaller pinholes and smaller intrinsic spatial resolution in the detectors. It is possible to improve the SPECT images by increasing the number of angular samples by a rotation of the collimator . The results obtained so far are very encouraging for the development of simultaneous SPECT/MRI.

References:

[1] S. Azman et al., "A nuclear radiation detector system with integrated readout for SPECT/MR small animal imaging", IEEE, Nuclear Science Symposium and Medical Imaging Conference, 2007, pp. 2311-17.

[2] M.J. Hamamura et al. "Development of an MR-compatible SPECT system (MRSPECT) for simultaneous data acquisition ", submitted to Phys Med. Bio. 2009.

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