Integrated 7T MRI and SPECT Systems for Small-Animal Imaging

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Purpose

MRI and single-photon emission computed tomography (SPECT) provide complimentary information which could aid in the diagnosis of various diseases. However, acquiring images from both modalities can been problematic. Until recently, SPECT systems could not be integrated with MRI systems due to the use of photomultiplier tubes which do not function in high magnetic fields. The development of semiconductor-based nuclear radiation detectors now allow for the operation of SPECT components within high magnetic fields. We have successfully operated such a SPECT system placed within the bore of a whole-body 4 T MRI system [1]. For a small-bore MRI system, a SPECT system could be placed immediately adjacent and co-axial to the magnet for efficient sequential imaging. Previously constructed 'back-to-back' systems were limited to MRI field strengths of only 0.1 T [2,3]. In this study, we present an integration of 7 T MRI and SPECT systems for small-animal imaging.

Methods

The general design of the integrated 7T MRI and SPECT systems is shown in Fig. 1. The nuclear radiation detector consists of 50.8×50.8×5 mm of cadmium-zinc-telluride (CZT) crystal coupled to 32×32 detector elements (1.6 mm pitch) with associated readout electronics (Gamma Medica, Inc., Northridge, USA). The detector was mounted in a plastic box covered with a thin copper mesh to provide EMI shielding. Coupled to the detector is a matched parallel-hole collimator made of a specialized lead composite that has reduced electrical conductivity to minimize its effect on the MRI [4]. The detector with collimator was mounted within a rotating gantry to allow for acquisition of the multiple views required for tomographic imaging. This gantry was placed immediately adjacent and co-axial to the bore of a 7 T MRI system. A 'patient couch' positioned along the central axis of the systems transfers the object to be imaged from one modality to the other.

To demonstrate operation of the combined systems, a balb/c mouse was injected *i.v.* with 2 mCi of ^{99m}Tc-sestimibi and sacrificed after 15 minutes to allow for radiotracer uptake. The mouse was then positioned within the SPECT scanner and nuclear radiation counts were recorded for 64 views equally spaced over 360 degrees, each for 60 seconds. A projection image was generated for each view using a ±5% energy window about the 140 keV photopeak. From these projection images, a 3D SPECT image was computed using filtered back-projection. Immediately after SPECT data acquisition, the animal was repositioned inside the 7T MRI system and data was acquired using a 2D fat-suppressed spin-echo pulse sequence with the following parameters: TR = 3.5 s, TE = 30 ms, FOV = 40×40 mm, matrix = 256×256, slice thickness = 1 mm, NEX = 2.

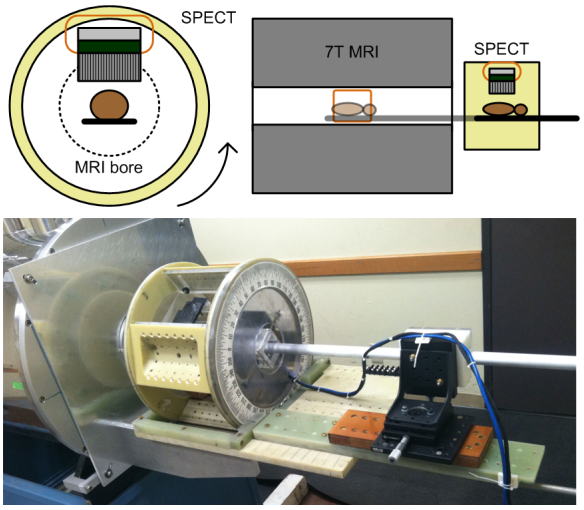

Fig. 1. *Axial view, side view, and photo of the integrated 7T MRI and SPECT systems*

Results

The MR, SPECT, and fusion images for several slices of the mouse are shown in Fig. 2. Radiotracer uptake is observed in the bladder, kidneys, and heart.

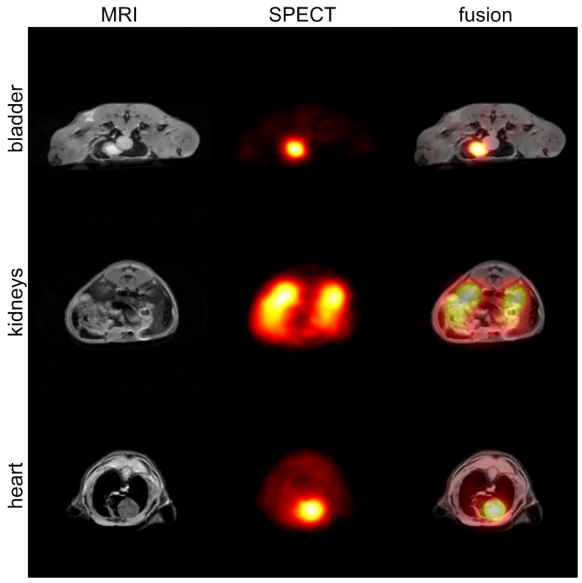

Fig. 2. *MR and SPECT images of the mouse*

Discussion

The results of this study demonstrate the feasibility of placing a SPECT system adjacent to a high-field, small-bore MRI system for sequential small-animal imaging. The use of CZT-based nuclear radiation detectors enables operation of the SPECT system in the presence of the fringe magnetic fields of the adjacent MRI system. Having these systems in close proximity allows for immediate back-to-back imaging, which should minimize motion of *in vivo* small animals between scans for improved spatial co-registration.

Our MR-compatible SPECT system is a modular unit that can be integrated with a wide variety of horizontal bore magnets. Its ability to work with existing high-field systems allows for combined SPECT and high-spatial resolution MR imaging with minimal integration costs and setup time. To improve the spatial resolution of the SPECT images, pinhole or cone-beam collimators could be utilized. To reduce the SPECT acquisition time, additional detectors could be added to the gantry.

Our combined systems will facilitate more detailed investigations into dual MR and SPECT imaging of various organs/diseases to more thoroughly assess its clinical value.

References

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