# Modular Rotating Gamma Camera Insert for Simultaneous SPECT and MR Small-Animal Imaging

Mark Jason Hamamura[1], Seunghoon Ha[1], Werner W Roeck[1], James W Hugg[2], Dirk Meier[3], and Orhan Nalcioglu[1,4]

[1]*Tu & Yuen Center for Functional Onco-Imaging, University of California, Irvine, CA, United States,* [2]*Gamma Medica, Inc., Northridge, CA, United States,* [3]*Gamma Medica, Inc., Fornebu, Norway,* [4]*Department of Cogno-Mechatronics, Pusan National University, Busan, Korea*

## Purpose

Simultaneous SPECT and MR imaging has numerous advantages and potential applications, including exact spatial and temporal co-registration, improved radiotracer quantification and SPECT spatial resolution, reduced overall scan time, and tracking of multiple biological probes. Until recently, SPECT systems could not be integrated with high-field 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 previously reported on the development of a small-animal SPECT imaging system that can be placed immediately adjacent and co-axial to high-field, small-bore MRI systems for efficient sequential imaging [1]. We have also successfully operated a limited small-animal SPECT system integrated within the bore of a whole-body 4 T MRI system [2]. In this study, we have further developed and tested a modular rotating gamma camera insert that has been designed for straightforward integration into any standard whole-body MRI system.

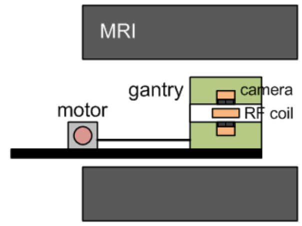


**Fig 1.** SPECT and MRI setup (not to scale)

## Methods

The general setup of the integrated SPECT and MRI systems is shown in Fig. 1. The SPECT system consists of two semiconductor-based gamma camera heads. Each camera head 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). Each detector was mounted in a lead-composite box for radiation shielding and covered with a thin copper mesh for EMI shielding. The cameras were mounted opposite to one another in a rotating gantry made primarily of G-10 Garolite plastic, stainless steel bearings, and a minimal number of brass fixtures for structural support (Fig 2a). The collimator associated with each camera can be interchanged; parallel-beam or converging-beam collimators can be coupled direct to the CZT crystals or pinhole collimators can be mounted in the gantry. The position of the cameras and any pinhole collimators can be adjusted to allow for different magnifications and FOVs. The entire gantry was placed within a whole-body 4 T MRI system (Fig 2b). An MR-compatible electric motor (Fig. 2c) was utilized to rotate the gantry. This novel device utilizes the main static magnetic field of the MRI in place of the conventional iron core [3]. For MR imaging, a custom-built RF coil was positioned within the center of the gantry. This coil was surrounded by copper mesh shielding to minimize coil tuning perturbations caused by the SPECT components (Fig 2d).

To demonstrate operation of this setup, we acquired simultaneous SPECT and MR images of a dual-isotope ($^{123}$I and $^{99m}$Tc99m) phantom and mouse implanted with vials containing $^{99m}$Tc using parallel-beam collimators. For each SPECT acquisition, nuclear radiation counts were acquired for 64 views equally spaced about 360 degrees, each for 30 seconds. A projection image was generated for each view using a ±5% energy window about the 140 keV photopeak. Each projection image was corrected for inherent nonuniform detector sensitivity and position shifting due to the Lorentz force. From these projection images, a 3D SPECT image was computed using filtered back-projection. Concurrent to SPECT data acquisition, MR images were acquired using a standard spin-echo pulse sequence.

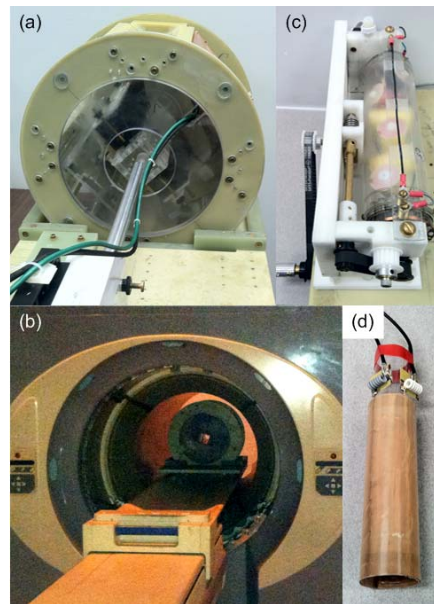


**Fig 2.** (a) Gantry, (b) Gantry in MRI, (c) Motor, and (d) RF coil

## Results

The MR, SPECT, and fusion images for the phantom and mouse are shown in Figs. 3 and 4 respectively. The phantom images further demonstrate the ability of this system to acquire multispectral SPECT images.

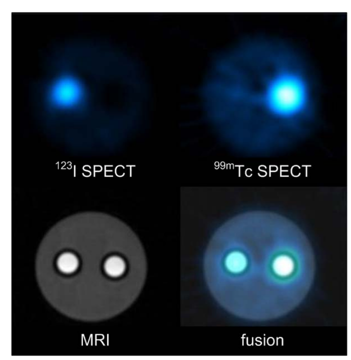


**Fig 3.** Dual-isotope phantom

## Discussion

The results of this study demonstrate the ability of our gamma camera insert to acquire simultaneous SPECT and MR images. Use of only two detector heads requires rotation to acquire a full dataset for tomographic reconstruction. Alternatively, an array of detectors can be positioned 360 degrees about the FOV at a significant increase in costs. The copper shielding surrounding the RF coil does attenuate radiation counts, but is necessary to minimize the adverse effects of the SPECT components. While this attenuation can be modeled in the reconstruction, the resulting images will suffer from a slight loss in SNR. Even with the shielding, the RF coil still suffers from a slight loss in efficiency, resulting in a small decrease of SNR in the MR images. These relatively minor SNR losses are necessary sacrifices for achieving simultaneous data acquisition. Never the less, we can still acquire accurate SPECT and MR images.

Our modular insert was designed specifically for straightforward integration into any standard whole-body MR system. Its ability to work with existing MRI systems allows for combined SPECT and MR imaging with minimal integration costs and setup time. Interchangeable collimation provides additional flexibility. Due to this versatility, we anticipate that this system can be utilized for a wide range of small-animal imaging applications.

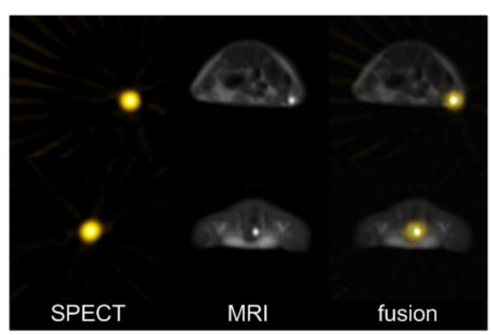


**Fig 4.** Mouse with radioactive vial implanted at different locations.

## References

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