Simultaneous, Dynamic SPECT-MRI Demonstrated in Three Small-Animal Prototypes

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Introduction: We have built and tested three SPECT (single-photon emission computed tomography) prototypes that can be inserted into MRI systems for simultaneous, dynamic imaging. Imaging a SPECT agent can provide a molecular imaging contrast for MR images at pico- to nano-molar sensitivities.

Materials and Methods: The MR-compatible solid-state Cadmium-Zinc-Telluride (CZT) gamma photon detector modules are 2.54 cm square and 5 mm thick with 16 x 16 pixels with 1.6 mm pitch. All digital readout electronics are included in the SPECT insert. Prototype SPECT insert #1 has multiple small gamma detectors and parallel-hole lead collimators placed between the rungs of the birdcage RF coil. The SPECT detectors and birdcage coil are rotated as a unit to collect SPECT projections views. Prototype SPECT insert #2 has 3 stationary rings of 8 CZT modules each and a rotatable cylindrical multiple-pinhole collimator. The shielded birdcage coil is placed outside the collimator. The outer diameter of prototype #2 is 12 cm and the insert fits inside the gradient coils of small-animal MRI systems with 20 cm diameter warm bores. Prototype SPECT insert #3 has 5 stationary rings of 19 CZT modules each. The shielded birdcage coil is placed inside the collimator and the 20 cm OD insert fits inside the gradient coils of 30 cm diameter warm bore MRI systems.

Results: We have measured and characterized the Hall Effect due to the Lorentz force [$F = q(E_{bias} + v \times B_0)$] on the electron and hole charge clouds created by gamma photon interactions in the CZT detectors. At 3T the electron cloud shifts on average 1.4 mm (about one pixel) across the 5 mm detector which can be accounted for in SPECT image reconstruction. The SPECT insert does not significantly affect the MR images and the SPECT images are not affected by the RF or gradient pulses. We have demonstrated in mice simultaneous SPECT and MR images (Fig. 1) and dynamic imaging of renal perfusion (Fig. 2). We are exploring the use of segmented MR images to provide gamma photon attenuation and scatter corrections as well as anatomical priors for quantitative SPECT image reconstruction.

Conclusions: SPECT-MRI has been demonstrated in small-animal prototype systems and is now available for drug discovery research applications. The SPECT and MR images can be acquired simultaneously, dynamically, and quantitatively, thus providing molecular imaging contrast for the MR images. The technology is nearly ready for translation to clinical applications including human brain, breast, and prostate imaging.

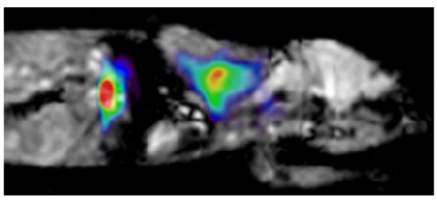

Fig. 1: ^{99m}Tc-sestamibi uptake in heart (& excreted to bladder) SPECT registered to gradient-echo image.

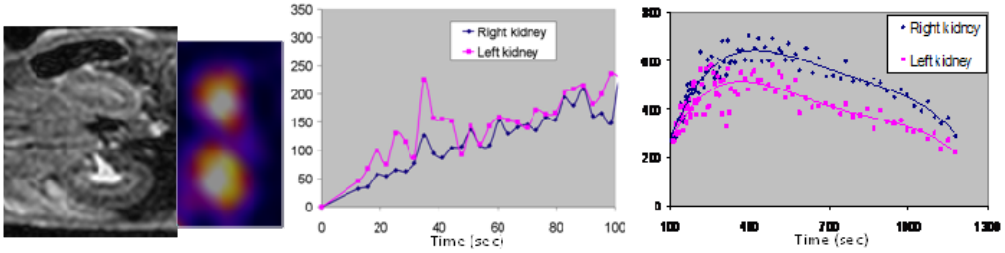

Fig. 2: 3D turbo-spin-echo image; ^{99m}Tc-DTPA dynamic SPECT in kidneys; 3s time bin dynamic renal perfusion for 20 min. Recirculation spike at ~36 s. 2nd graph continues with different scale.

References: Wagenaar, *et al*, *Technol Cancer Res Treat* 2006, 5:343; Hamamura, *et al*, *Phys Med Biol* 2010, 55:1563; Hamamura, *et al*, *Technol Cancer Res Treat* 2010, 9:21.

Funded by NIH grants R44-EB6712 & R01-EB8730; CIRM grant RT1-01120; Research Council of Norway. Protected by US patents 7,629,586 & 7,786,444 & patents pending.