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CHARACTERIZATION OF AN MRI-COMPATIBLE PRE-CLINICAL PET INSERT WITH FIRST RESULTS IMAGING A RAT MODEL OF STROKE

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INTRODUCTION

- The fusion of pre-clinical molecular imaging methods such as PET and MRI will provide new pathways for discovery in science and medicine by enabling superior spatial and temporal resolution compared to clinical systems.
- We recently evaluated a versatile MR compatible small animal PET insert called NuPET (Fig. 1A) in collaboration with Cubresa Inc. which enables true simultaneous pre-clinical PET/MRI studies.
- We evaluate several PET performance characteristics following NEMA NU 4-2008 guidelines[1] and report our first experience using the system to simultaneously collect PET and MRI in a longitudinal model of ischemic stroke in rats.

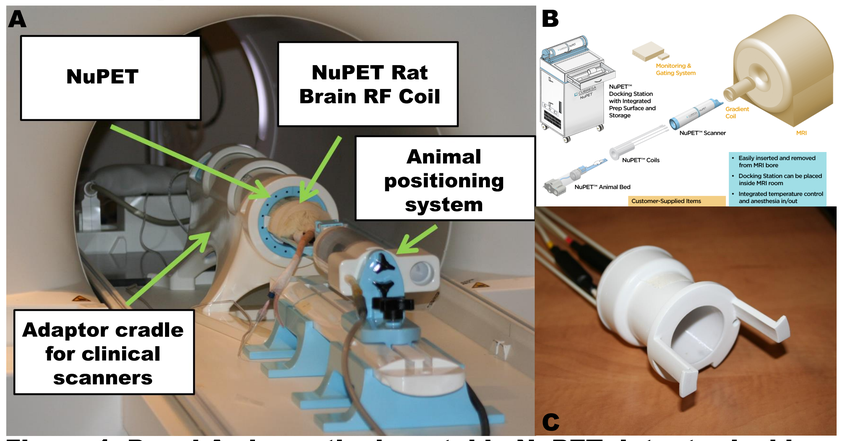

Figure 1: Panel A shows the insertable NuPET detector inside the adaptor cradle together with a rat brain RF coil and translatable animal positioning bed. Panel B, the vendor schematic and panel C is a close-up of the RF coil.

METHODS

- All experiments were performed under approved animal ethics (CCAC) and isotope use licences (CNSC).
- An insertable PET system (NuPET, Fig. 1A) was positioned inside a clinical 3T PET/MRI together with a rat brain RF coil (Fig. 1C). The NuPET consists of two detector rings each with 16 detectors (totalling 32) with a field of view of 58.9mm (trans-axial) by 67.2mm (axial).
- A NEMA NU 4-2008 image quality (IQ) phantom[1] (Fig. 2A) was imaged using the NuPET for 20 min with 4MBq of [^{18}F]-FDG added in order to measure uniformity, recovery coefficients (RC) and spill over ratios (SOR).

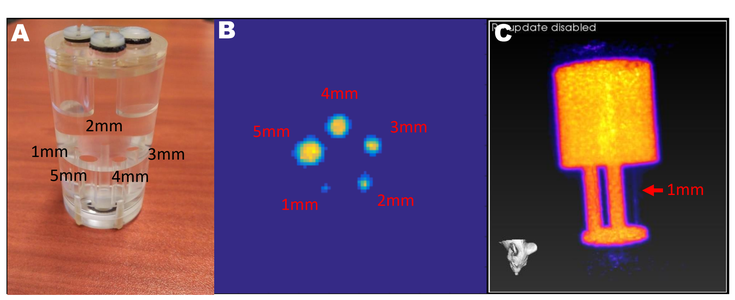

Figure 2: The NEMA NU 4-2008 IQ phantom demonstrating system resolvability down to 1mm.

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- Detector sensitivity was measured using a 50.32kBq ^{22}Na point source, stepped through the z-axis of the NuPET in steps of 0.64mm using an Arduino-controlled stepper motor. Three minutes of acquisition was performed for each position in order to meet a minimum of 10k counts[1] for each position. The energy window was 250-750 keV.
- Fischer 344 rats were imaged using simultaneous PET/MRI (Fig. 5). Rats were injected with 30MBq [^{18}F]-FEPPA [i.v.] and imaged for 45 min.
- PET phantom images were reconstructed to 0.64 x 0.64 x 0.64mm^3 with scatter correction using the STIR package as well as an intrinsic detector geometry MLEM 3D (PSF) reconstruction.

RESULTS

- A PET image of the IQ phantom is shown in Figure 2 demonstrating good PET image quality and resolvability of 1mm features within the IQ phantom using a 50 iteration PSF reconstruction algorithm.
- We measured the absolute detector sensitivity and report a peak sensitivity value of 7.49% (Fig. 3) which is comparable to the vendor's published value of 5.8%[2] under the same reconstruction conditions.

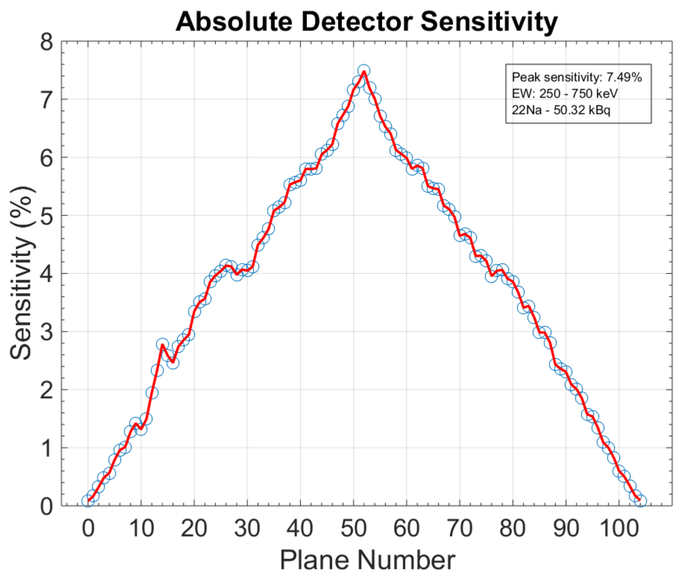

Figure 3: Measurement of absolute detector sensitivity yielding a peak sensitivity value of 7.49% compared to the vendor published value of 5.8%[2].

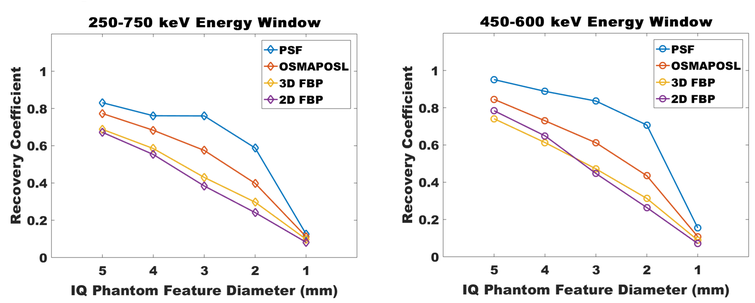

Figure 4: Recovery coefficients at energy windows of 250-750 keV and 450-600 keV for four different reconstruction methods: PSF, OSMAPOSL, 3D FBP and 2D FBP.

- From the IQ phantom PET image, we measured values of 9.8% and 11.3% for uniformity, 28.9% and 19.4% for water SOR, 10.6% and 1.6% for air SOR, 83.1% and 95.1% for RC 5mm and finally 12.6% and 15.6% for RC 1mm for energy windows of 250-750 keV and 450-600 keV respectively. Table 1 outlines the complete results for uniformity and SOR and Figure 4 outlines all measured RCs.

250-750 keV	Uniformity %STD	SOR Water	SOR Air	RC 5mm	RC 1mm
2D FBP	11.08	31.61	15.76	67.23	8.19
3D FBP	9.428	35.05	17.21	68.76	9.75
OSMAPOSL	11.348	33.84	18.18	77.28	11.2
PSF	9.802	28.99	10.6	83.09	12.61
450-600 keV	**Uniformity %STD**	**SOR Water**	**SOR Air**	**RC 5mm**	**RC 1mm**
2D FBP	11.46	22.467	6.876	78.39	7.12
3D FBP	7.877	25.41	8.56	74.05	8.93
OSMAPOSL	10.213	25.937	10.99	84.48	10.82
PSF	11.312	19.384	1.556	95.13	15.54

Table 1: Measured values of uniformity, SOR water, SOR air and RCs at 5mm and 1mm for four different reconstruction methods and at two different energy windows.

- We used our PET insert to simultaneously acquire PET and MRI data at baseline, 7 days and 30 days post stroke in rats. Figure 5 demonstrates changes observed in the amount of tracer located around the site of the stroke compared to baseline.

DISCUSSION

- The PET detector is set up inside the bore of the MRI for truly simultaneous PET/MRI while maintaining ideal co-localization conditions between PET and MR images during acquisition.
- We measured several performance characteristics such as sensitivity, uniformity, RCs and SORs. Measured sensitivity was higher and uniformity was lower than those stated while RCs and SORs were similar in value, all compared to the vendor's published values within the user's manual[2].
- Finally, we utilized the system to perform simultaneous PET/MRI in rats that had undergone stroke induction using [^{18}-F]-FEPPA, and at three timepoints. This tracer is sensitive to activated microglia known to correlate with white matter inflammation. The images appear to have good quality, are free of artifacts and were very easy to register in post-processing.
- Future work involves completion of system characterization by measurement of resolution, noise equivalent count rate and mutual system interaction.

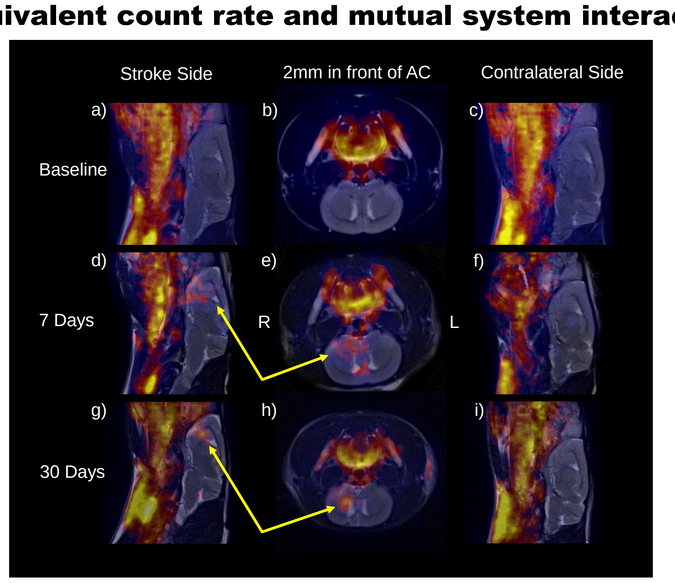

Figure 5: Simultaneous PET/MRI fusion in a longitudinal rat model of stroke. Elevated uptake was observed at the expected site of stoke in panels d), e) and later in g) and h).

References:

[1]: National Electrical Manufacturers Association (NEMA). NEMA standards Publication NU 4-2008: Performance Measurement for Small Animal Positron Emission Tomographs. Washington DC. NEMA

[2]: Cubresa NuPET User's Manual: UM 6620 04 Rev 2