NEMA NU 2–2007 measurements and GATE Monte Carlo simulations of GE Signa integrated PET/MR for different PET isotopes

<u>P. Caribé</u>¹, M. Koole², A. Diogo³, Y. D'Asseler¹, S. Vandenberghe¹ ¹Ghent University, Medical Imaging and Signal Processing – MEDISIP, Gent, Belgium ²KU Leuven, Division of Nuclear Medicine and Molecular Imaging – UZ/KU, Leuven, Belgium ³Faculty of Sciences of the University of Lisbon (FCUL), Department of Physics, Lisbon, Portugal

Introduction: NEMA characterization of PET systems is generally done with ¹⁸F. However, other PET isotopes such as ⁶⁸Ga and ⁹⁰Y are gaining clinical importance as they are of specific interest for oncological applications and for follow up of radionuclide therapy. However, the physical properties of these PET isotopes are quite different and there may be a larger interference with the magnetic field of the MR compared to ¹⁸F. Therefore, it is relevant to determine the performance of PET/MR for clinically relevant isotopes.

Method: The aim was divided into two parts: (1) NEMA NU 2–2007 tests were performed for characterizing the spatial resolution (SR), sensitivity, image quality (IQ) and NECR for ¹⁸F, ⁶⁸Ga and ⁹⁰Y. NECR was performed using ¹⁸F and ⁶⁸Ga. (2) Modelling of a realistic GATE Monte-Carlo model of the GE Signa PET/MR to investigate the effect of the 3T MR field on positron range of ¹⁸F, ¹¹C, ¹⁵O, ¹³N, ⁸²Rb and ⁶⁸Ga for different tissue types.

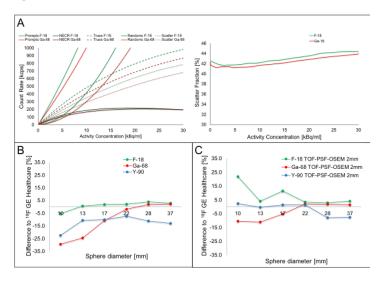
Results: NEMA tests for ¹⁸F, ⁶⁸Ga and ⁹⁰Y resulted in substantially different system characteristics. The SR is about 1mm larger in the axial direction (compared to ¹⁸F). The impact of this lower resolution is also visible in the recovery coefficients of the smallest spheres of ⁶⁸Ga in IQ tests (Figure 1B and C), where clearly lower values are obtained compared to ¹⁸F. The differences in sensitivity are due to the scale factor from the positron emission fraction of the isotopes. The peak NECR was lower than for ¹⁸F and appears at higher activities (Figure 1 A). The positron range (Table 1) is a tissue-dependent and increase in the z-direction by a factor 3-4 when compared to the range in x/y direction in the lung tissue for high-energy positrons.

Conclusion: The system performance of GE Signa integrated PET/MR was substantially different, in terms of NEMA SR, IQ and NECR for ⁶⁸Ga compared to ¹⁸F. For ⁹⁰Y the resolution is comparable to ⁶⁸Ga and the low number of counts leads to a large variability in the IQ measurements. For some isotopes a correction in the reconstruction algorithm is necessary.

Table 1 Mean positron range for different tissues and radioisotopes at 3 T.

			Mean 3D Range		nge	Mean x or y Range			Mean z Range		
	Max	EnergyBraching	Ratio(mm)			(mm)			(mm)		
	(keV)	(%)	Soft	Lung	Bone	Soft	Lung	Bone	Soft	Lung	Bone
¹⁸ F	633.5	99.86	0.52	1.70	0.34	0.26	0.73	0.17	0.27	1.08	0.17
11 C	960.2	99.75	0.96	1.97	0.51	0.48	0.63	0.25	0.51	1.52	0.26
¹³ N	1198.5	99.82	1.01	2.63	0.69	0.49	0.74	0.34	0.54	2.15	0.35
¹⁵ O	1732.0	99.89	1.66	4.28	1.17	0.77	0.97	0.57	0.93	3.74	0.61
⁶⁸ Ga	1899.0	87.90	2.04	4.59	1.26	0.95	1.00	0.61	1.16	4.04	0.66
⁸² Rb	3378.0	95.45	3.82	10.12	2.74	1.62	2.25	1.28	2.42	8.96	1.55

Figure:



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