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

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**Introduction:** NEMA characterization of PET systems is generally done with $^{18}$F. However, other PET isotopes such as $^{68}$Ga and $^{90}$Y 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 $^{18}$F. 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 $^{18}$F, $^{68}$Ga and $^{90}$Y. NECR was performed using $^{18}$F and $^{68}$Ga. (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 $^{18}$F, $^{11}$C, $^{15}$O, $^{13}$N, $^{82}$Rb and $^{68}$Ga for different tissue types.

**Results:** NEMA tests for $^{18}$F, $^{68}$Ga and $^{90}$Y resulted in substantially different system characteristics. The SR is about 1mm larger in the axial direction (compared to $^{18}$F). The impact of this lower resolution is also visible in the recovery coefficients of the smallest spheres of $^{68}$Ga in IQ tests (Figure 1B and C), where clearly lower values are obtained compared to $^{18}$F. 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 $^{18}$F 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 $^{68}$Ga compared to $^{18}$F. For $^{90}$Y the resolution is comparable to $^{68}$Ga 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 Ratio(mm) | | | Mean x or y Range (mm) | | | Mean z Range (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Max (keV)** | **EnergyBraching (%)** | **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:**