^{188}Re image performance assessment using small animal multi-pinhole SPECT/PET/CT system

Pedro L. Esquinas[a], Cristina Rodríguez-Rodríguez[a,b], José Carlos De La Vega[b], Mehrdad Bokharaei[b], Katayoun Saatchi[b], Maryam Shirmohammad[a], Urs O. Häfeli[b], Vesna Sossi[a] and Anna Celler[c]

[a]*Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, V6T 1Z1, Canada*

[b]*Faculty of Pharmaceutical Sciences, University of British Columbia, Vancouver, BC, V6T 1Z3, Canada*

[c]*Department of Radiology, University of British Columbia, Vancouver, BC, V5Z 1M9, Canada*

Corresponding Author

Name: Pedro L. Esquinas

Tel: (+1) 604 875-5252

Email: esquinas@phas.ubc.ca

SUPPLEMENTAL MATERIAL

S.1 VECTor/CT calibration experiments

In order to obtain 3-D activity distribution, the reconstructed images were re-scaled using a Calibration Factor (*CF*) that converts the voxel values (arbitrary units) into activity concentration (MBq/mL). The *CF* was obtained from the reconstructed image of a point source of well-known activity using the following expression:

$$CF = \frac{A}{V \sum R_i}, \tag{1}$$

where *A* represents the point source activity (in MBq), measured using a dose calibrator (Atomlab 500, Biodex), *V* represents the voxel volume in the reconstructed image (in mL) and $\sum R_i$ represents the sum of voxel values in a volume of interest (VOI) drawn around the point source. A 1% threshold was applied to segment the point source within the drawn VOI.

The CF depends on the isotope, collimator and energy window settings. In this study, the CF was measured for ^{188}Re (UHRC and HE-UHRC) using a 79 MBq point source scanned during 15 minutes. Similarly, the CF was also measured for ^{99m}Tc (UHRC and HE-UHRC) using a 37 MBq point source scanned during 15 minutes. The point source images were reconstructed using the same window settings and corrections described in the manuscript (Section 2.1.2). The measured calibration factors were 3398 MBq/mL, 3100 MBq/mL, 551.8 MBq/mL and 466.9 MBq/mL for ^{188}Re-UHRC, ^{188}Re-HE-UHRC, ^{99m}Tc-UHRC and ^{99m}Tc-HE-UHRC, respectively.

S.2 Calculation of image contrast and contrast-to-noise ratio

Image contrast and CNR *vs* rod diameter were quantified using images of the same Micro-Jaszczak resolution phantom following the method described by Walker *et al*. 2014 [1] ([21] in the original manuscript). For each image, cylindrical ROIs (5 mm height) were placed on each rod and in the space between the rods. The diameter of each ROI was 0.9 times the diameter of the analyzed rod. The image contrast was defined as:

$$C_d = \frac{\overline{h_d} - \overline{b_d}}{\overline{h_d}}, \quad (2)$$

where $\overline{h_d}$ represents the average voxel value of all ROIs drawn on the hot rods within a section of rod diameter *d*. Similarly, $\overline{b_d}$ represents the average voxel value of all ROIs drawn in between the rods (i.e., in the background). The noise N_d was defined as the variability between ROI mean values, and was calculated as:

$$N_d = \frac{\sqrt{\sigma_{h_d}^2 + \sigma_{b_d}^2}}{\overline{rois_d}}, \quad (3)$$

where $\sigma_{h_d}^2$ and $\sigma_{b_d}^2$ represent the standard deviation of h_d and b_d respectively and $\overline{\mathrm{rois}_d}$ represents the mean value of all ROIs (h and b) within the sector with rods having diameter *d*. The Contrast-to-Noise ratio (CNR) was calculated as C_d/N_d.

S.3 Monte-Carlo model of VECTor/CT

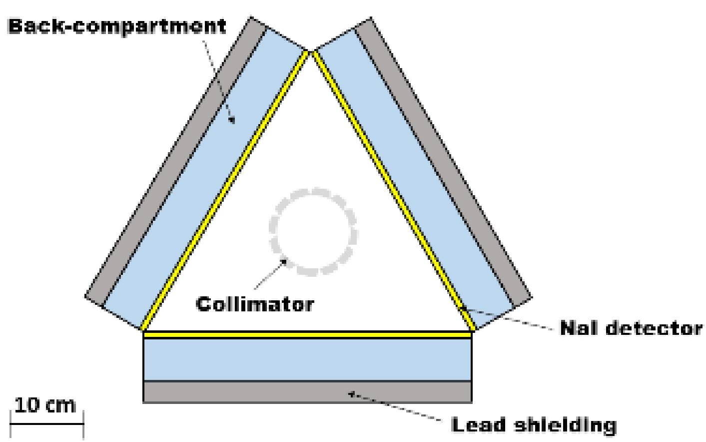

Fig. 1 Diagram of VECTor geometry modelled with GATE

The Monte-Carlo model of the VECTor system included: three 9.5 cm thick NaI detectors covered by a 0.05 cm thick aluminum layer at the front. The back-compartment region of the detector contained a 0.95 cm thick light-guide made of glass followed by 5.65 cm of an uniform material modeling the photomultiplier tubes made of 23% glass, 56% vacuum and 21% air [2]. In addition, three lead panels (3 cm thickness) were added to model the shielding material around the system. Only the UHRC collimator was simulated. For the sake of simplicity, the UHRC was modelled as a Tungsten hollow cylinder with a 9.8 cm bore diameter (van der Have et al. 2009[3], [14] in the original manuscript) and 1.5 cm thickness containing a single ring of pinholes at the center of the tube (15 pinholes in total). The pinhole diameter for this collimator was set to 1 mm, and the opening angle was 30^{o} (Vaissier et al. 2012[4], [27] in the original manuscript). Fig. 1 shows a cross-section of the VECTor geometry modeled with Monte-Carlo.

The ^{188}Re decay data was built-in in GATE, and it is based on the Evaluated Nuclear Structure Data File (ENSDF) database (Bhat 1992[5]). The detector energy resolution R (FWHM) was set at R_0 =10% for E_0 =140 keV photons. The dependence of resolution R with photon energy was modeled as an inverse square root law ($R(E) = R_0 E_0/\sqrt{E}$). Only photons which deposited energies in the range 50 keV to 700 keV in the detector were recorded.

A total of 10^8 decays of ^{188}Re were launched for each of the simulations described in the manuscript, Section 2.4.2. The modelling of the system and simulations were performed using Geant4 Application for Tomographic Emissions (GATE), version 6.1 [6,7]([33,34] in the original manuscript).

S.3 References

[1] Walker MD, Goorden MC, Dinelle K, Ramakers RM, Blinder S, Shirmohammad M, et al. Performance Assessment of a Preclinical PET Scanner with Pinhole Collimation by Comparison to a Coincidence-Based Small-Animal PET Scanner. J Nucl Med 2014;55:1368–74.

[2] Rault E, Staelens S, Van Holen R, De Beenhouwer J, Vandenberghe S. Accurate Monte Carlo modelling of the back compartments of SPECT cameras. Phys Med Biol 2011;56:87–104..

[3] van der Have F, Vastenhouw B, Ramakers RM, Branderhorst W, Krah JO, Ji C, et al. U-SPECT-II: An Ultra-High-Resolution Device for Molecular Small-Animal Imaging. J Nucl Med 2009;50:599–605.

[4] Vaissier PEB, Goorden MC, Vastenhouw B, van der Have F, Ramakers RM, Beekman FJ. Fast Spiral SPECT with Stationary gamma-Cameras and Focusing Pinholes. J Nucl Med 2012;53:1292–9.

[5] Bhat MR. Evalutated Nuclear Structure Data File (ENSDF). Nucl Data Sci Technol 1992:817–21..

[6] Jan S, Santin G, Strul D, Staelens S, Assi K. GATE : a simulation toolkit for PET and SPECT. Phys Med Biol 2004;49:4543–61.

[7] Jan S, Benoit D, Becheva E, Carlier T, Cassol F, Descourt P, et al. GATE V6: a major enhancement of the GATE simulation platform enabling modelling of CT and radiotherapy. Phys Med Biol 2011;56:881–901.