PhD Thesis Title: Investigation and Correction for the Partial Volume Spill in Effects in Positron Emission Tomography

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Abstract:

Positron emission tomography (PET) imaging has a wide applicability in oncology, cardiology and neurology. However, there is a major drawback when imaging very active regions, such as the bladder and the bone, which is the spill in effect. This leads to inaccurate quantification and obscured visualisation of nearby lesions. Therefore, this thesis aims to investigate and correct the spill in effect from high activity regions to the surrounding regions using the background correction technique. It also investigates the effect of activity in the hot region, lesion size and location, system resolution as well as application of post-filtering on the spill in effect.

This thesis involved analytical simulations for the digital 4D extended cardiac-torso version2 (XCAT2) phantom, and validation acquiring data from National Electrical Manufacturers Association (NEMA) phantoms and patient datasets with the General Electric (GE) Signa PET/MR and the Siemens Biograph mMR and mCT scanners. Reconstructions were done using the ordered subset expectation maximisation (OSEM) algorithm. Dedicated point spread function (PSF) and the background correction (BC) were incorporated into the reconstruction for the spill in correction. For the region of interest (ROI) analysis, semi-automated ellipsoidal ROIs were drawn on the exact location of the lesions. Afterwards, these were used to extract the standardized uptake value (SUV). The bias, recovery coefficient (RC), coefficient of variation (CoV) and contrast-to-noise ratio (CNR) were computed from the SUVs. Then, these were used as figures of merit to compare the performances of all the reconstruction algorithms.

The thesis revealed: (i) lesions within 15-20 mm from the hot region are predominantly affected by the spill in effect, leading to an increased bias and impaired lesion visualisation within the region; (ii) the spill in effect is further influenced by the ROI selection criteria, increased activity in the hot region, reduced system resolution and application of post-filter; (iii) the spill in effect is more evident for the SUV_{max} than the SUV_{mean}; (iv) for proximal lesions (within 2 voxels around the hot region), the PSF has no major improvement over OSEM because of the spill in effect when coupled with the Gibbs effect; (v) with OSEM+PSF+BC, the spill in contribution from the hot region was removed in all cases (irrespective of ROI-selection, proximity of lesion to hot region, or application of post-filter), thereby enhancing quantification accuracy and contrast in lesions with low uptake.

This thesis concludes that the BC technique is effective in correcting the spill in effect from hot regions to surrounding regions of interest. It is also robust to ROI-induced errors and post-filtering.

References to author publications that relate specifically to the dissertation:

1. **Mercy I. Akerele**, Nouf A. Mushari, Rachael O. Forsythe, Maaz Syed, Nicolas A. Karakatsanis, David E. Newby, Marc R. Dweck, and Charalampos Tsoumpas (2020). "Assessment of different quantification metrics of [18F]-NaF PET/CT images of patients with abdominal aortic aneurysm." *Journal of Nuclear Cardiology*. DOI: 10.1007/s12350-020-02220-2.

2. **Mercy I. Akerele**, Nicolas A. Karakatsanis, Daniel Deidda, Jacobo Cal-Gonzalez, Rachael O. Forsythe, Marc R. Dweck, Maaz Syed, David E. Newby, Robert G. Aykroyd, Steven Sourbron, and Charalampos Tsoumpas (2020). "Comparison of Correction Techniques for the Spill in Effect in Emission Tomography." *IEEE Transactions on Radiation and Plasma Medical Sciences*. DOI: 10.1109/TRPMS.2020.2980443.

3. **Mercy I. Akerele**, Nicolas A. Karakatsanis, Rachael O. Forsythe, Marc R. Dweck, Maaz Syed, Robert G. Aykroyd, Steven Sourbron, David E. Newby, and Charalampos Tsoumpas (2019). "Iterative reconstruction incorporating background correction improves quantification of [18F]-NaF PET/CT images of patients with abdominal aortic aneurysm." *Journal of Nuclear Cardiology*. DOI:10.1007/s12350-019-01940-4.

4. **Mercy I. Akerele**, Palak Wadhwa, Jesus Silva-Rodriguez, William Hallet and Charalampos Tsoumpas (2018). "Validation of the physiological background correction method for the suppression of the spill-in effect near highly radioactive regions in positron emission tomography." *European Journal of Nuclear Medicine and Molecular Imaging Physics,* 5:34. DOI: 10.1186/s40658-018-0233-8.

5. **Mercy I. Akerele,** Daniel Deidda, Jacobo Cal-Gonzalez, Nicolas A. Karakatsanis, Rachael O. Forsythe, Marc R. Dweck, Robert G. Aykroyd, Steven Sourbron, and Charalampos Tsoumpas (2018). "Improved correction techniques to compensate for partial volume and spill-in effects in Pet." *IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)*, pp. 1-5. DOI: 10.1109/NSSMIC.2018.8824282.

6. **Mercy I. Akerele**, Palak Wadwha, Stefaan Vandenberghe, and Charalampos Tsoumpas (2017). "Comparison of partial volume correction techniques for lesions near high activity regions." *2017 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)*, pp. 1-7. DOI: 10.1109/NSSMIC.2017.8532638.