Whole-Body dynamic PET: Effect of temporal gaps on FDG $K_i$ quantification from 3D and 4D reconstruction algorithms

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Introduction and study setup

- In whole-body (WB) dynamic PET imaging, acquisition is performed sequentially over bed positions to achieve whole body coverage, introducing large temporal gaps in the accepted data.
- The objective of this work is to study the effect of temporal gaps on quantification of FDG $K_i$ from Patlak analysis and compare reconstruction methods and acquisition protocols.
- The brain Zubal [1] phantom was used to simulate dynamic scans for a single bed and 3 different WB protocols. The reconstruction methods listed below were evaluated over 50 noise replicates.
- 3D: Frame by frame 3D reconstruction, followed by post reconstruction Patlak analysis.
- 4D Spectral: Dynamic reconstruction with Spectral basis functions (4, 7 or 15) and Nested-EM [2], followed by post reconstruction Patlak analysis.
- 4D Patlak: Direct Patlak dynamic reconstruction within the Nested–EM framework, using the Patlak coefficients as time basis functions.

Analysis and Results

- **Patlak analysis performed at the ROI (Cortex) level**: In this analysis all algorithms converge to similar levels of $K_i$ bias. For the SB protocol convergence is slower due to the higher number of frames, but in the case of WB protocols all reconstructions demonstrate similar convergence behaviour.

**ROI TAC Metrics**

\[ TAC_{ROI}(\text{Cortex}) = K_i(\text{ROI}) \]

ROI Bias and Stdv over replicates $\mathcal{R}$:

\[ \text{ROI Bias}_0 = \frac{\sum_{i=1}^{N} \left( R_{i}^{\text{GT}} - R_{i}^{\text{ROI}} \right)^2}{\sum_{i=1}^{N} R_{i}^{\text{GT}}} \]

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- **Patlak analysis performed at the voxel level (parametric imaging)**: Analysis over the Cortex ROI showed for 3D reconstruction and post-recon ordinary least squares fitting that $K_i$ bias increases with iteration and doesn’t converge. In contrary both 4D algorithms demonstrate convergence, with similar bias levels to the TAC ROI analysis above.

**Parametric ROI TAC Metrics**, for voxels $j \in \text{Cortex}$

\[ TAC_{ROI}(j) = K_i(j) \]

**Parametric ROI Bias and Stdv over replicates $\mathcal{R}$:**

\[ \text{ROI Bias}_{0,j} = \frac{\sum_{i=1}^{N} \left( R_{i}^{\text{GT}} - R_{i}^{\text{ROI}} \right)^2}{\sum_{i=1}^{N} R_{i}^{\text{GT}}} \]

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**Voxel-wise ROI Metrics**, for Cortex ROI

**Mean over replicates $\mathcal{R} := \overline{R}_j$**

**Ground truth $\overline{R}_j$**

\[ \text{Bias}_{ROI} = \frac{\sum_{i=1}^{N} R_{i}^{\text{GT}}(\overline{R}_j - R_{i}^{\text{ROI}})^2}{\sum_{i=1}^{N} R_{i}^{\text{GT}}} \]

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Conclusions and Future directions

- All 4D reconstruction algorithms in WB protocols provided $K_i$ estimates with lower stdv than that of 3D reconstruction in WB and SB protocols.
- For the simulated non-reversible two tissue compartment models, the Spectral model with 4 exponentials showed better performance over the algorithms with higher number of exponentials and direct Patlak 4D reconstruction, for all cases of WB acquisition protocols.
- A comparison of WB protocols shows that WB2 and WB3 have better performance over WB1, in terms of bias and noise levels.
- Further evaluation using non-linear fitting methods and direct reconstruction with non-linear models is required to better differentiate for the differences between whole-body dynamic protocols, as these models are more sensitive to the noise of the dynamic data.

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