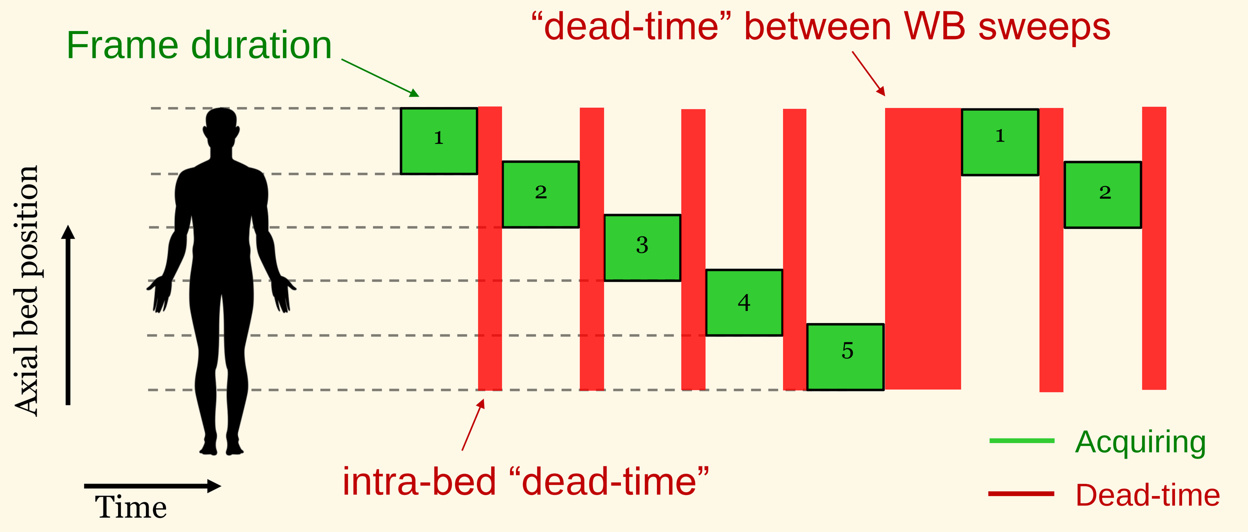
HYBRID - Healthcare Yearns Bright Researchers for Imaging Data.
An Innovative Training Network (H2020 MSCA-Innovative Training Network: No 765448)
www.hybrid2020.eu

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

Zacharias Chalampalakis*, Simon Stute*, Marina Filipović*, Thibaut Merlin†, Claude Comtat*
* Service Hospitalier Frédéric Joliot, CEA, Inserm, CNRS, Univ. Paris Sud, Univ. Paris Saclay, Orsay, France
† LaTIM, INSERM 1011, CHRU de Brest, France

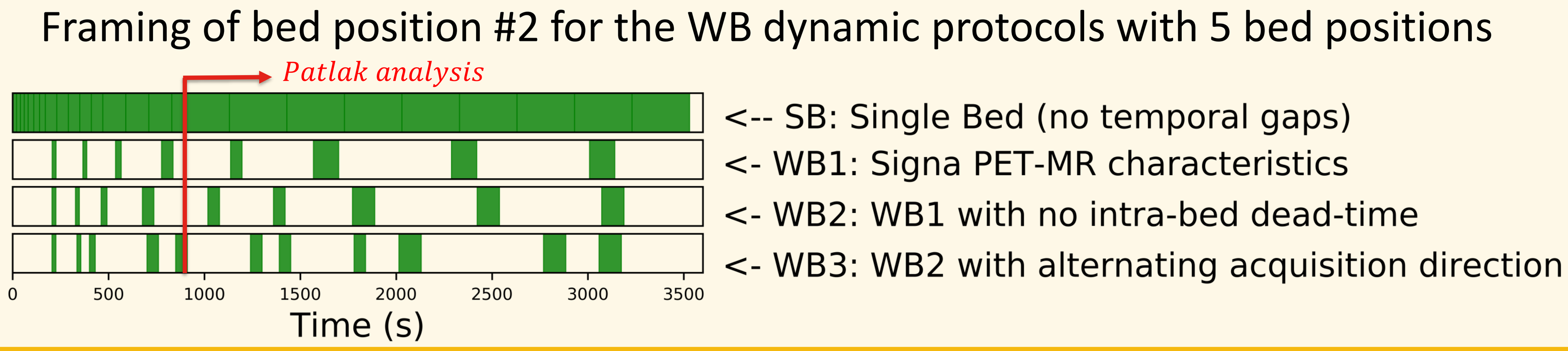
Introduction and study setup

- 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 acquired data.
- The objective of this work is to study the effect of temporal gaps on quantification of FDG Ki 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 bellow 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.



Example WB acquisition protocol of 5 Beds

Framing of bed position #2 for the WB dynamic protocols with 5 bed positions



[1] Zubal *et al*. Med. Phys., vol. 21, pp. 229-302, 1994. [2] Wang *et al*. Phys. Med. Biol., vol. 55, pp. 1505-1517, 2010.

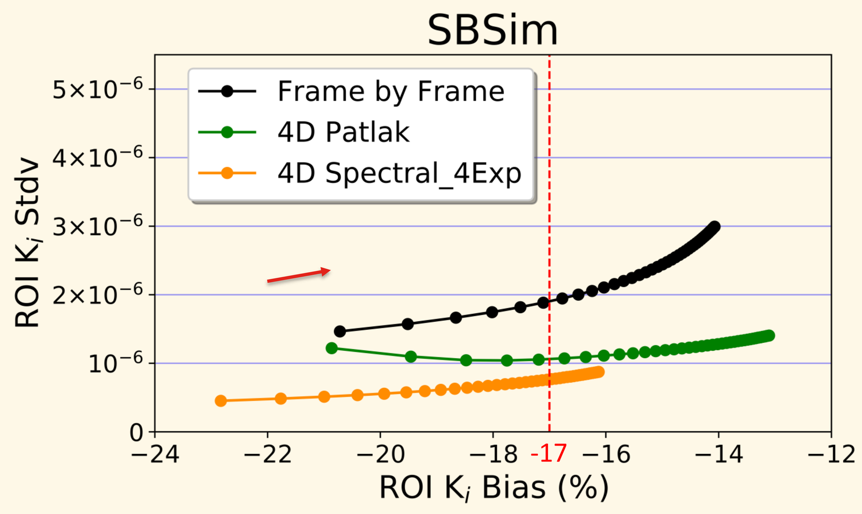
Analysis and Results

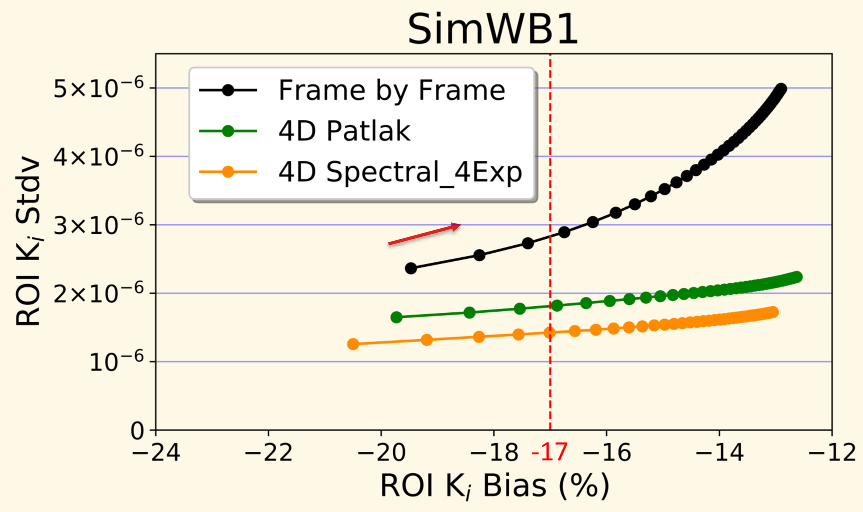
- **Patlak analysis performed at the ROI (Cortex) level:** In this analysis all algorithms converge to similar levels of Ki bias. For the SB protocol convergence is slower due to the higher number of frames, but in the case of WB protocols all reconstructions demonstrate similar convergence behaviour.

ROI TAC Metrics

$$TAC_{\mathfrak{R}}(Cortex) \xrightarrow{Patlak} K_{i\,\mathfrak{R}}(Cortex)$$

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





Standard deviation values for bias level of -17%

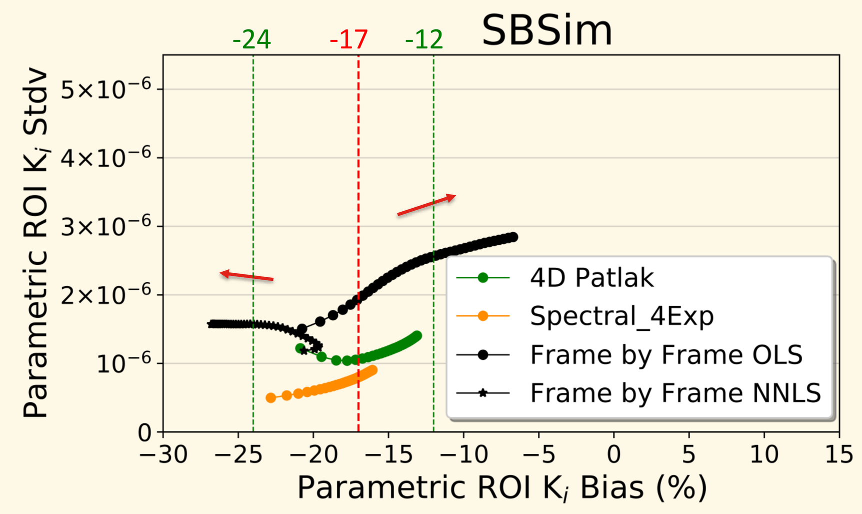
	SB	WB1	WB2	WB3
Frame by Frame	1.88E-06	2.89E-06	2.49E-06	2.90E-06
4D Patlak	1.05E-06	1.82E-06	1.55E-06	1.73E-06
4D Spectral_4Exp	**7.69E-07**	**1.42E-06**	**1.19E-06**	**1.09E-06**
4D Spectral_7Exp	1.92E-06	1.56E-06	1.30E-06	1.26E-06
4D Spectral_15Exp	1.45E-06	1.56E-06	1.31E-06	1.26E-06

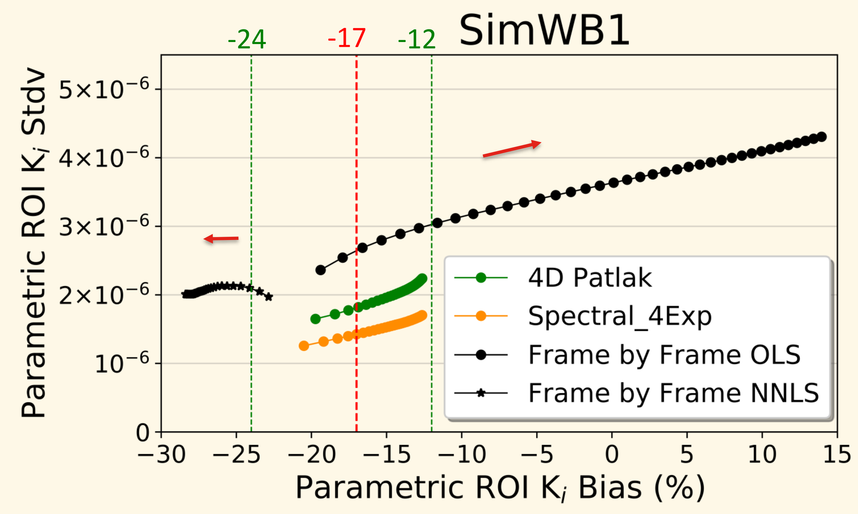
- **Patlak analysis performed at the voxel level (parametric imaging):** Analysis over the Cortex ROI showed for 3D reconstruction and post-recon ordinary least squares fitting that Ki bias increases with iteration and doesn't converge. In contrary both 4D algorithms demonstrate convergence, with similar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

Parametric ROI Metrics, for voxels $j \in Cortex$

$$TAC_{\mathfrak{R}}(j) \xrightarrow{Ptlk} K_{i\,\mathfrak{R}}(j \in Cortex) \coloneqq \theta_j$$

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





Standard deviation values for bias level of -17%

	SB	WB1	WB2	WB3
Frame by Frame OLS	1.93E-06	2.69E-06	2.45E-06	2.68E-06
4D Patlak	1.05E-06	1.82E-06	1.55E-06	1.73E-06
4D Spectral_4Exp	**8.03E-07**	**1.42E-06**	**1.23E-06**	**1.09E-06**
4D Spectral_7Exp	2.10E-06	1.54E-06	1.29E-06	1.25E-06
4D Spectral_15Exp	1.57E-06	1.56E-06	1.29E-06	1.26E-06

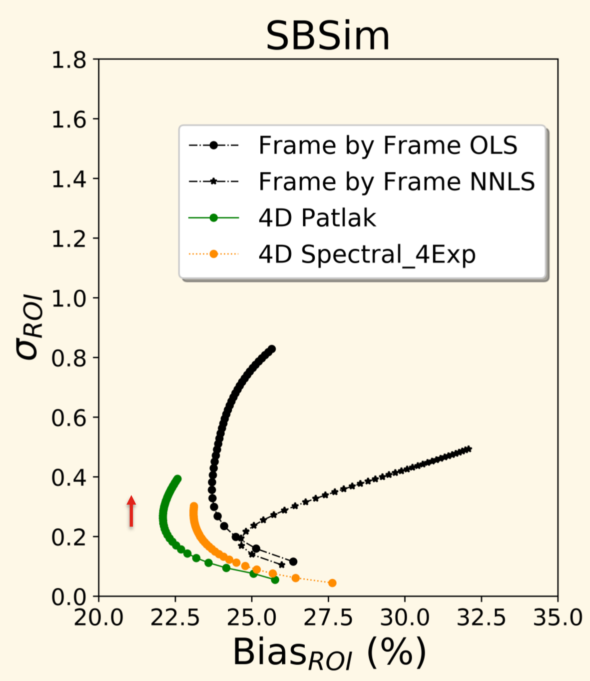
Voxel-wise ROI Metrics, for Cortex ROI

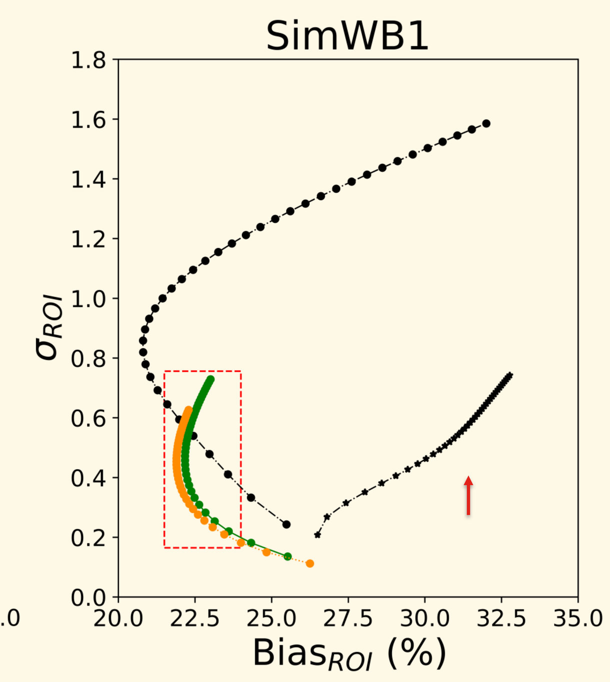
Mean over replicates $\mathfrak{R} \coloneqq \bar{\theta}_j$

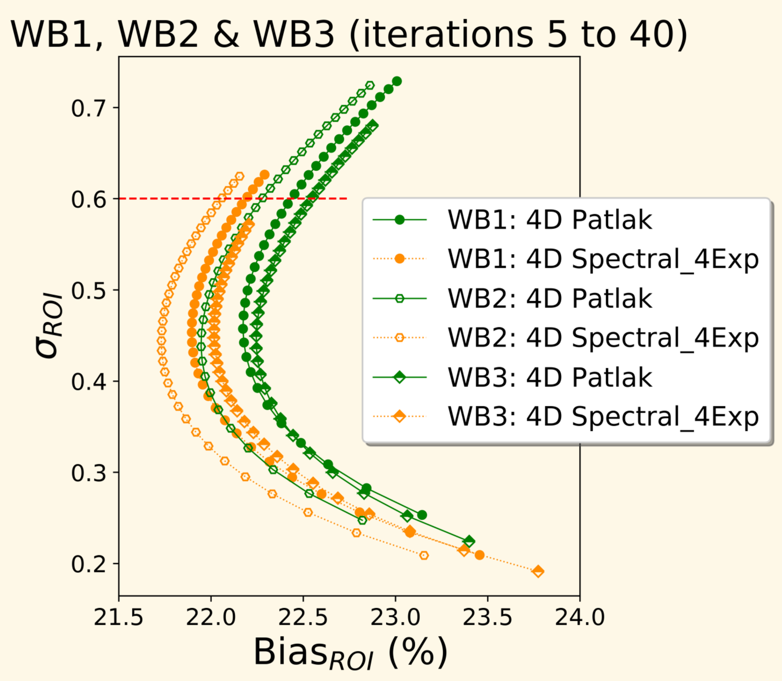
Ground truth θ_j^{GT}

$$Bias_{ROI} = \sqrt{\frac{\sum_j^{N_{ROI}} (\bar{\theta}_j - \theta_j^{GT})^2}{\sum_j^{N_{ROI}} (\theta_j^{GT})^2}}$$

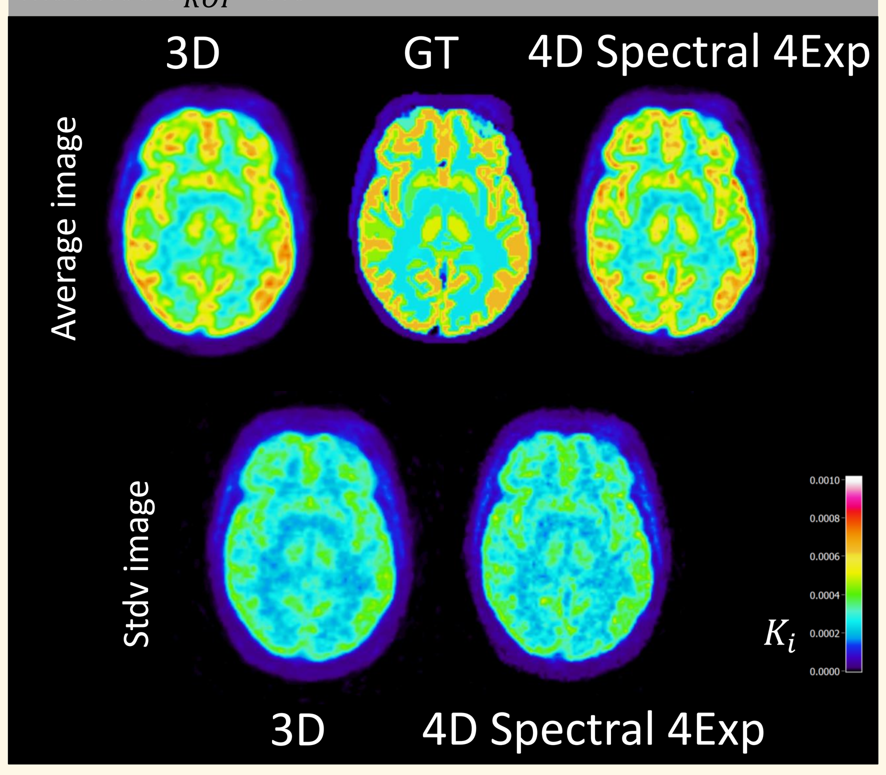
$$\sigma_{ROI} = \sqrt{\frac{\sum_n^{\mathfrak{R}} \sum_j^{N_{ROI}} (\bar{\theta}_j - \theta_{j,n})^2}{N_{\mathfrak{R}} \sum_j^{N_{ROI}} (\theta_j^{GT})^2}}$$







Mean and Stdv images from SimWB1 at iterations with matched σ_{ROI}= 0.6



Conclusions and Future directions

- All 4D reconstruction algorithms in WB protocols provided Ki 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.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 764458.
www.hybrid2020.eu