Simultaneous ^{18}F-FACBC PET/MRI for loco-regional staging of prostate cancer: considerations on imaging protocol design

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Target audience: Physicians and physicists with a special interest in PET/MRI and/or staging of prostate cancer

Purpose: PET/CT imaging of 1-amino-3-fluorine 18-fluorocyclobutane-1-carboxylic acid (^{18}F-FACBC) has shown promising results for the assessment of primary and metastatic prostate cancer [1,2], especially in conjoint use with MRI [3]. PET/MRI may be interesting for this patient group, since this hybrid technology enables simultaneous acquisition of PET and multiparametric MR images. However, designing an imaging protocol that does not compromise image quality is complicated by the fast tracer kinetics of ^{18}F-FACBC and the long scan time required for multiparametric MRI. By analyzing the dynamic uptake of ^{18}F-FACBC, we aim to find the optimal imaging protocol for simultaneous ^{18}F-FACBC PET/MRI in the setting of loco-regional staging of prostate cancer.

Methods: Until October 2014, 11 patients were consecutively enrolled in an ongoing prospective study to investigate the potential of simultaneous ^{18}F-FACBC PET/MRI for staging of high-risk prostate cancer. An integrated PET/MRI exam (3 T Biograph mMR, Siemens, Erlangen, Germany) was performed approximately one week before radical prostatectomy with extended lymph node dissection. Acquisition of PET/MR data was performed in two bed positions (BP1: prostate in isocenter; BP2: covering prostate and pelvic lymph nodes) as detailed in Figure 1. To evaluate the dynamic uptake of the tracer, PET list-mode data were binned into 20 and 4 time bins for BP2 (4 x 15, 4 x 30, 4 x 60, 6 x 120 and 2 x 180 seconds) and BP1 (4 x 300 seconds), respectively, before reconstruction (HDPET, 344 x 344 matrix, 3 iterations, 21 subsets, 4 mm FWHM Gaussian filter). Whole prostate and whole bladder VOIs and VOIs in 10 subsequent transverse slices with pelvic bone, external iliac arteries, small/large intestines, and glutei maximi were manually delineated on the T2 SPACE images using 3D Slicer (www.slicer.org) [4] and resampled to the positions and dimensions of both PET bed positions. For each patient, dynamic curves of standardized uptake vales (SUVs) were calculated for all VOIs by multiplying the mean activity concentration (Bq/ml) in the VOI by the patient weight (g) divided by the net injected activity (Bq). Finally, mean dynamic SUV curves (averaged over all patients) and standard deviations were calculated for all VOIs. Matlab (Mathworks, Natick, MA, USA) was used for image processing.

Duration	Start scan	30 min	Tracer inj.	25 min	20 min
Localization		BP1: prostate isocenter		BP2: prostate & lymph nodes	BP1: prostate isocenter
PET		None		List-mode	List-mode
MRI		Localizer, tcsT2WI, tDWI		MRAC, cT1WI, cDWI, cT2 SPACE	MRAC, MRSI, tDCE-MRI

Figure 1: Schematic overview of the PET/MR protocol. t: transverse; c: coronal; s: sagittal plane; T2WI: T2-weighted imaging; DWI: diffusion-weighted imaging; MRAC: MR for attenuation correction; T1WI: T1-weighted imaging; MRSI: MR spectroscopic imaging; DCE-MRI: dynamic contrast enhanced MRI

Results: All PET and MR images were successfully acquired except for spectroscopic imaging in 2 patients. The median injected activity was 323 MBq (range 292–351). The median time lag between injection and start of PET acquisition (BP2) was 59 seconds (range 25–120). Figure 2 shows fast initial uptake in all VOIs except for the bladder. The SUV was higher in the prostate than in any other VOI between 2.5 and 15 minutes post-injection.

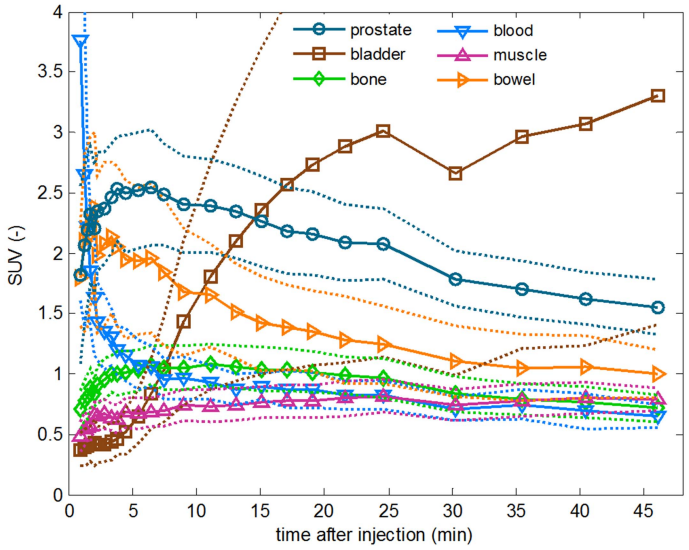

Figure 2: Average dynamic uptake curves (solid lines + markers) +/- standard deviation (dashed lines) for all VOIs

Discussion: The analysis of dynamic tracer uptake presented in this work indicates that PET acquisition should start immediately after ^{18}F-FACBC injection and should last at least 15 minutes. Based on these results and on our initial experience with ^{18}F-FACBC PET/MRI, we propose an optimized imaging protocol as detailed in Figure 3. Moving T2-weighted imaging of the prostate (tcsT2WI) from BP1 to BP2 facilitates less switching between bed positions, while still taking full advantage of the Glucagon that is intravenously injected before scanning to reduce bowel movement. In addition, it enables continuous PET imaging of the prostate and pelvic lymph nodes for 45 minutes. Diffusion-weighted imaging of the prostate (tDWI) must be performed in BP1, since the gland should be in isocenter to minimize distortion artefacts. Due to the later time of imaging in the optimized protocol, injection of Buscopan may be required to reduce bowel movement.

Duration	Start scan	5 min	Tracer inj.	45 min	25 min
Localization		Initial		BP2: prostate & lymph nodes	BP1: prostate isocenter
PET		None		List-mode	None
MRI		Localizer		MRAC, tcsT2WI, cT1WI, cDWI, cT2 SPACE	tDWI, MRSI, tDCE-MRI

Figure 3: Schematic overview of the proposed optimized PET/MR protocol.

References: **1** Nanni et al, Clin Genitourin Cancer, 2014. 12(2):106-10. **2** Schuster et al, J Urol, 2014. 191(5):1446-53. **3** Turkbey et al, Radiology, 2014. 270(3):849-56. **4.** Fedorov et al, Magn Reson Imaging, 2012. 30(9):1323-41.