Dual-modality evaluation of tumour vasculature, morphology and metabolism via Dynamic Susceptibility Contrast MRI and FluoroEthyl Choline-PET using simultaneous PET/MR

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Background & Purpose: Gadolinium extravasation in neuro-perfusion Dynamic Susceptibility Contrast Magnetic Resonance Imaging (DSC-MRI) has been shown to cause inaccuracy in the estimation of cerebral blood volume and blood flow [1]. Correction methods typically include post-processing and so-called *pre-loading* which entails using a pre-saturation bolus of Gd. Kinetic parameters indicative of underlying physiology can be evaluated in the post-processing stages, in the manner of Boxerman et al [2], or through employing a dual-echo approach in the manner of Barbier et al & Quarles et al [3,4] separating the T_1 and T_2* effects of the Gd, allowing simultaneous acquisition of DCE and DSC MRI. These two approaches are investigated here using a simultaneous PET/MRI system in order to obtain a thorough parametric analysis of tumour morphology, metabolism and angiogenesis; factors that are essential for accurate tumour staging and treatment planning. Practical benefits of this system include improved temporal efficiency and inherent spatial and temporal registration of PET and MR images.

Methods: *Hardware:* SIEMENS 3T Biograph mMr. *Software:* Matlab R2013b. *MRI Acquisition Parameters:* 10 ml Gd injected at 3 ml/s, For Boxerman analysis: Single-shot T_2 weighted, slice-interleaved EPI, TE= 31ms, TR=3s, 1.7*1.7*4 mm^3, 29 slices, 49 dynamics. Dual echo approach: Spoiled 2D multi-slice dual-echo GRE, slice interleaved, 50 dynamics, TE_1=8ms, TE_2=20ms.TR=24ms. 3 flip-angles pre-Gd (3,8,16) for T_{10} map. *PET Acquisition Parameters:* Max 370 MBq ^{18}F-FECho, Dyn scans: 19 dynamics, 127 slices. Attenuation Corr: MR Dixon segmentation.

Results: Data were analysed from three patients diagnosed with astrocytoma, one patient with a high grade thalamic glioblastoma and five patients with pineal germinoma. One of the astrocytoma subjects was scanned with the dual-echo acquisition protocol. Overall, astrocytoma showed a significantly higher rCBV and Boxerman transfer coefficient, K_2, relative to other tumour types. Pineal germinoma showed a high deviation in all MR derived parameters. The physical variation in tumour morphology and proximity to the pineal glands complicates the analysis for this tumour type.

Tumour type	*rCBV ratio*	*Avg ADC (10^{-6} mm^2/s)*	*Avg SUV (kBq/ml)*	*K_2 (1/s)*
Astrocytoma(n=2)	4.045 +/-0.316	1374 +/- 159	3.11 +/- 2	0.0489+/-0.0039
Pin. Germinoma(n=5)	1.2 +/-1.25	3791 +/- 2945	1.61 +/- 0.2963	0.0003+/-0.0043
Thalamic glioblastoma(n=1)	1.4	1220	2.86	-0.0027

Table 1*: rCBV tumour/rCBV white matter, average ADC, SUV and transfer coefficients for all patients scanned with EPI protocol.*

The dual echo approach inherently provides a T_1 correction and kinetic information relating to tumour physiology. However, any parametric maps generated from the DSC analysis suffer from signal loss in regions containing susceptibility borders. Echo times must be chosen carefully to balance the T_1 and T_2 weighting to obtain sufficient SNR. PET ^{18}F-FECho PET uptake shows tumour cell membrane turnover and lipid metabolism indicative of tumour aggressiveness. Necrotic regions in e.g. astrocytoma should be excluded from the analysis. *Fig 1* shows raw echo signals as a function of time for tumour ROIs generated by the dual-echo technique. *Fig 2* shows two patients diagnosed with astrocytoma scanned with an *a)* EPI and *b)* dual-echo acquisition protocol. For comparison, a transfer coefficient map is shown displaying low K_2 values for the dual-echo, proving the validity of this technique in eliminating T_1 dominated extravasation. PET parametric maps show specific uptake and differentiation between necrotic and tumourous tissue.

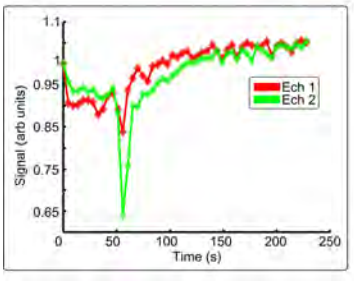

Fig 1 Raw echo signal as a function of time from dual-echo

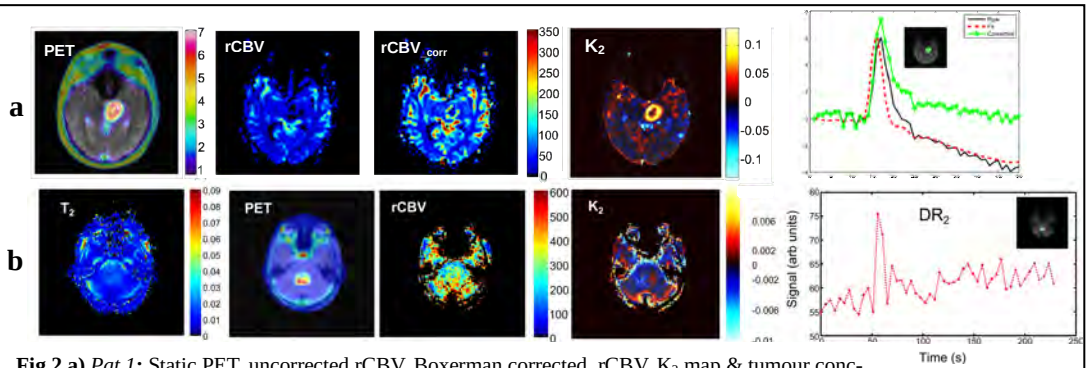

Fig 2 a) *Pat 1*: Static PET, uncorrected rCBV, Boxerman corrected rCBV, K_2 map & tumour conc-time curve,fit and corrected fit. **b)** *Pat 2:* T_2 map, static PET, rCBV,K_2 & tumour ΔR_2

Conclusion & Future work: Simultaneous ^{18}F-FECho PET and contrast enhanced MRI provides complementary dynamic information relating to tumour vasculature, morphology and aggressiveness, thus showing potential as a tool in tumour staging. The use of post-processing corrections or dual-echo acquisition strategies allows rapid kinetic information to be gained and the DSC data to be intrinsically void of T_1 effects. More patients with glioma and germinoma are in the process of being scanned with both protocols and will be added to the analysis.

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