Title: A Non-invasive Method for Quantifying Cerebral Blood Flow by Hybrid PET/MR

Trainee Name: Tracy Ssali

Supervisor(s): Dr. Keith St Lawrence

Structured Abstract:

Introduction: Positron emission tomography (PET) with radiolabeled water (15O-water) is considered the gold standard for imaging cerebral blood flow (CBF). However, quantification requires measuring the arterial input function (AIF), an invasive procedure. Arterial spin labeling (ASL) is an attractive MRI-based alternative, but its accuracy is hindered by arrival time uncertainties, particularly when imaging CBF in patients with cerebrovascular diseases. We propose a hybrid PET/MR approach where global CBF is measured by phase-contrast MRI (PC-MRI), simultaneously with PET imaging of 15O-water. Global CBF is used as a reference to convert PET activity data into CBF maps, thereby avoiding the need to measure the AIF. In this study, global and regional agreement between simultaneously measured CBF was compared in a large animal model over a range of CBF values.

Methods: Data were acquired in juvenile pigs (n = 8, 20 ± 3 kg) at hypo-, normo-, and hypercapnia. The arterial carbon dioxide tension (pCO2) was varied by manipulating the breathing rate and volume thereby altering the CBF. After a rapid intravenous bolus injection of 15O-water (423±130 MBq), 5 min of PET list-mode data were acquired with the Siemens 3T PET/MR system. Arterial blood was sampled at 5mL/min using an MR-compatible blood sampling system. For PC MRI, an imaging plane orthogonal to the internal carotid and basilar arteries was identified by time-of-flight angiography. Gated PC images were acquired simultaneously with PET scanning. For structural reference, sagittal MPRAGE T1-weighted images were acquired.

Average whole brain flow was measured with PC-MRI data by contouring the feeding arteries in MATLAB and scaling by the brain tissue weight. Raw PET data were reconstructed using a CT-based attenuation correction map. Images were smoothed and a non-linear optimization routine was used to fit the Kety model including a blood volume term to determine CBF.

Results: Mean pCO2 at the 3 conditions were 29.0±3.6, 39.7±2.2 and 54.3±7.3 mmHg. Whole-brain CBF measured by PC-MRI were: 36.5±6.6, 54.3±6.6 and 92.3±8.4 ml/100g/min and 15O water-PET were: 34.3±6.0, 57.5±10.0 and 87.4±10.6 ml/100g/min at hypo-, normo- and hypercapnia. Linear regression and Bland-Altman plots were used to assess agreement between regional and global CBF values measured by the two approaches.

Discussion and Conclusion: This work presents a non-invasive and quantitative method of imaging CBF by hybrid MR/PET. This method could be useful for patient populations for whom it has proven challenging to obtain accurate perfusion measurements with other methods, most notably ASL, due to significant vascular disease. Linear regressions showed strong positive correlation (R2>0.9). The Bland-Altman plot demonstrated good agreement between PET and MRI measurements (NS, p=0.22). Future studies will involve comparing this reference method to ASL in CVD patients to assess its ability to quantify perfusion abnormalities.