Title: Analysis of metabolism in guinea pig placentae using an optimized flip angle scheme

Trainee Name: Lauren Smith

Supervisor(s): Dr. Charles McKenzie

Structured Abstract:

Introduction: Hyperpolarized (HP) magnetic resonance imaging (MRI) of carbon-13 (13C) allows real-time quantitative imaging of key biological molecules, such as pyruvate and its downstream metabolites, and as such is useful as a non-invasive method to examine placental metabolism. A challenge of HP imaging is the rapid decay of the HP state (20-40 seconds for pyruvate in vivo), leading to issues of low spatial resolution and signal-to-noise ratio (SNR). We have addressed the issue of low SNR by implementing a hybrid flip angle (HFA) scheme which uses a unique flip angle for each metabolite that varies over the time of the acquisition. We hypothesize that using the HFA for HP 13C-pyruvate MRI will boost the SNR and provide a more precise measurement for quantitative analysis of the metabolic rate.

Methods: The HFA scheme produces a different flip angle trajectory for each metabolite by progressively varying both the shape and amplitude of the spectrally selective RF shape for each image acquisition, to optimize the signal of each metabolite during the experiment. The pulse shape and amplitude are updated at the beginning of each acquisition and maintained throughout the acquisition. The HFA scheme was compared to a constant flip angle (CFA) scheme where a spectrally selective pulse is used to produce a unique flip angle for each metabolite but does not vary with respect to time. Six pregnant guinea pigs were imaged at 3T (Discovery MR750, GE Healthcare, Waukesha, WI) using a custom built 13C birdcage coil (Morris Instruments, Ottawa, Canada). 75mg/kg of the HP 80mM [1-13C]pyruvate was delivered as a bolus injection via IV catheter into a hind leg vein over approximately 12 seconds. Image acquisition began 7.5 seconds after start of bolus injection and images were acquired every 7.5 seconds. Each animal was imaged using both the CFA and HFA scheme (in a randomized order) and T1 images were acquired for anatomic reference. SNR was calculated as the mean signal in regions of interest (ROIs) drawn around the placentae divided by the standard deviation of signal in a noise ROI. A previously published (1) fitting algorithm was adapted for this data and used to estimate the metabolic rate of conversion of pyruvate to lactate (kPL) in the placenta ROIs.

Results: We have demonstrated that the HFA scheme provides an overall boost in SNR in the placenta relative to a CFA acquisition for all animals. SNR is most notably elevated at later time points, observing an SNR >5 30s after injection. Data acquired using the HFA scheme had a smaller error when used to estimate the kPL compared to data acquired with CFA.

Discussion: Our in vivo data suggests that the HFA scheme was successful in preserving signal during acquisition compared to the CFA scheme. The SNR boost from the HFA scheme allows for a more precise estimation of kPL. This technique has been implemented in ongoing imaging studies.