Arterial input function by DNP measurement using an automated injector designed for a 7T unshielded magnet

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Introduction

We are using dynamic nuclear polarisation (DNP), a technique for increasing the sensitivity of MRI, to assess the effects of changes in oxygenation on tumour metabolism. In order to improve our model of the metabolic process in tumours, we have measured the arterial input function (AIF) using the hyperpolarised pyruvate signal. Because AIF is dependent on injection rate, we have standardised our injections by building a fully MR compatible automated injector for use with an unshielded 7T magnet.

Methods

P22 sarcomas were transplanted sub-cutaneously on the rear dorsum of BDIX rats. Five animals were tail cannulated (1 artery, 2 veins) to provide blood pressure monitoring, anaesthetic and pyruvate delivery. Each rat was placed head first into the magnet and one venous cannula was routed so that it passed next to the lower side of a 20mm ^{13}C /^{1}H surface coil. This was performed in order to provide a hyperpolarised reference signal whose decay was due to both T_1 and the effect of rf pulses. ^{1}H angiography was measured in order to visualise the major arteries for DNP localisation, where little metabolism takes place. These were chosen to provide a pyruvate AIF. Pyruvate was hyperpolarised using a 'HyperSense' system (Oxford Instruments) and 1.5ml (0.5 ml dead volume) was injected using a custom made automatic injector. 1D ^{13}C spectra were acquired (localised using a 20mm surface coil and slice select spectroscopy) every second with a 20 degree flip angle. Polarisation levels were typically 20-25%.

MR compatible automated injector

The automated injector is a hydraulic system utilising dual infuse/withdraw syringe pumps situated outside the magnet room. Mounted on each syringe pump is a 10ml BD disposable syringe filled with distilled water. Both 10ml syringes were connected, via 5mm O.D. water filled tube to a 2.5 ml BD syringe mounted in an acetal chassis, figure 1. The use of differing syringe volumes in the hydraulic circuit allows flow rate to be geared to the desired rate beyond the nominal capability of the driving syringe pump. The 2.5ml syringes were mounted on a sliding carriage to allow a push/pull motion. A third syringe, also mounted on the carriage, was connected to a pyruvate receiving vessel and an I.V cannula through a bidirectional check valve. The syringe pumps operate in reciprocating mode allowing the pyruvate to be drawn out of a receiving vessel and injected into a venous cannula via the bidirectional check valve. The desired injection rate and volume could then be set on the master syringe pump, whose start timing was controlled by a Bruker Avance II MR console. An injection speed of 9ml/min was used to deliver a 1.5ml bolus injection over 10s. Accuracy of delivery of 39 µl was achieved with the injector.

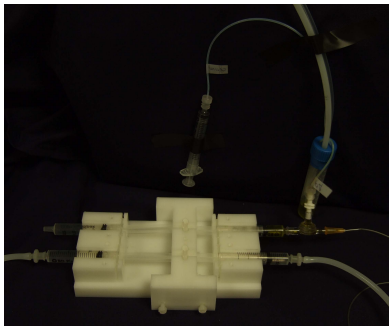

Figure 1: Hydraulically drive automated MR compatible syringe pump.

Results and discussion

The pyruvate signal was measured in a phantom to provide a fixed reference *in vitro* through the cannula line, slice 1 of figure 2 and *in vivo* in the major arteries, slice 2 of figure 2. The pyruvate signal in figure 3 shows a later maximum value and a faster decay rate for the *in vivo* signal compared to the in vitro signal. This illustrates the dispersion of the signal during transit along the arterial tree. However, the similar shape of the two signals may allow the use of the signal from the I.V. line to be used as an AIF for all experiments, where major artery experiments are not possible.

The signal from the major arteries can now be used as an input to the two way exchange model [1] to account for a more physically realistic AIF and provide more accurate estimates of the pyruvate and lactate metabolic fluxes under the influence of different conditions. The signal from the *in vitro* line can be used to provide constraints to the AIF and effective T_1 relaxation time and RF flip angle θ.

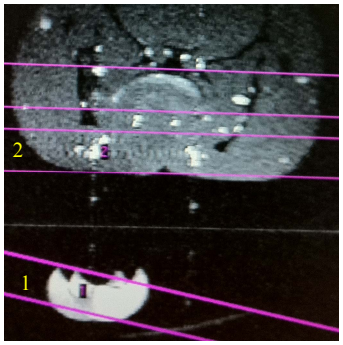

Figure 2: Structural slices: (1) through th phantom and in vitro line and (2) through the major arteries.

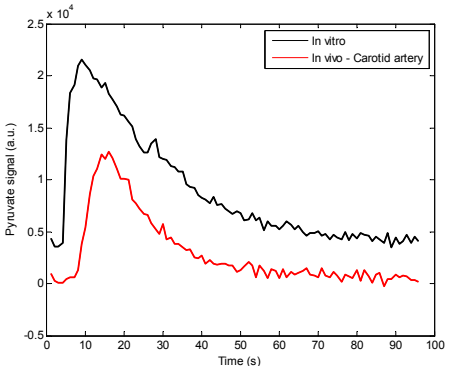

Figure 3: Pyruvate signal in vitro (cannula) and in vivo (AIF major arteries).

References

[1] Day SE, et al. Nat Med., 2007, 13, 1382-7