MAGNETIC CARRIER FOR HYPERPOLARIZED ^{13}C SAMPLE TRANSFER FROM DNP POLARIZER TO MR SCANNER

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Target Audience Hyperpolarized (HP) ^{13}C MRI researchers.

Purpose Hyperpolarized ^{13}C-substrates can lose polarization extremely quickly in low magnetic fields as they are transferred from a polarizer to a scanner, reducing the MR SNR. One example is a compound with scalar coupling between fast relaxing quadrupolar ^{14}N and ^{13}C, such as in ^{13}C-urea[1]. In order to preserve polarization, previous methods used ^{15}N labeled urea or carrying a permanent magnet close to sample during its transfer[1,2]. The former has a high cost and creates a doublet ^{13}C resonance. The latter is unsafe since the permanent magnet could fly into the scanner. This magnetic carrier was constructed to provide a uniform and suitable magnetic field for the safe transfer of HP samples.

Methods The key part of the device is a solenoid with current (~0.5 A) to generate magnetic field (> 50 Gauss over 6 cm long section). The circuit is shown in Figure 1, with a lithium polymer non-magnetic battery. It can be carried into the scanner room and turned off there. The current is only on when depressing the pushbutton momentary switch, which causes the device to be turned off automatically in the scanner room as one lets go. The size was customized for the specific 3mL and 5mL syringes used typically for preclinical HP ^{13}C studies at our site.

Relative measurements were performed to test the effect of the magnetic carrier on HP ^{13}C-urea and copolarization of urea and pyruvate. After dissolution, the HP samples were divided into two syringes with the same amount, carried to the scanner (~7s) with one in the carrier, the other in the ambient low field. The solutions were then injected into two other syringes already fixed in a mouse ^{13}C-coil lying parallel along z direction. For the urea-only test, the axial images were acquired with a 90 degree RF pulse and EPI readout with projection along the z direction. For urea-pyruvate tests, dynamic 1D MRSI was acquired with projections along y and z directions. Signal at thermal equilibrium was measured to compensate for differences in the amounts of HP urea in each syringe; TE=140ms, TR=1s.

Results A THM 7025 magnetometer was used to measure the field inside the solenoid. Since the size of the probe was larger than the inner diameter of the solenoid, a prototype solenoid with larger size was made to test the accuracy of the field simulation by comparisons with the measured results. The field simulation was based on the Biot-Savart Law and the approximation that the solenoid is a group of current loops. The calculated results were close to the actual result, but slightly lower in the center. Using the same simulation menthod, we calculated the field of the device to be > 50 G over a 6 cm section in the center, shown in Figure 2.

In relative measurements, the HP ^{13}C-urea transported with this device showed a 2 fold SNR improvement compared to the one carried in the low field, while the HP ^{13}C-pyruvate is not affected, shown in Figure 3 and Table 2.

Figure 1. Circuit diagram(left), photo of the solenoid inside (center) and the whole device(right).

Coil wire	22 AWG, 6 layers, 727 turns, 2.9 Ohm
Coil size	First layer diameter 1.65 cm, length 7.95 cm
Battery	500 mAH, 3.7 V, LiPo battery, non-magnetic
Switch	Normally Open Pushbutton Momentary Switch
Current	I-LED=0.0021 A, I-coil=0.5007 A,
Resistor	R1=833 Ohm, R2=4.4 Ohm
Duration	1h

Table 1. Circuit component parameters and system details.

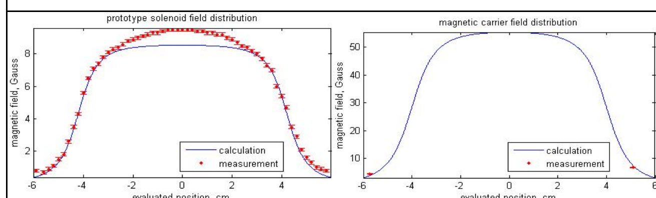

Figure 2. Comparison of magnetic field simulation and measurement for a prototype solenoid (left) and the device (right).

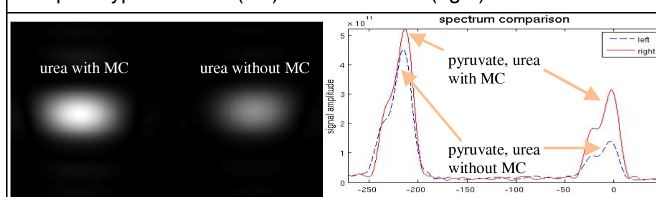

Figure 3. Relative measurement to test the effect of the magnetic carrier(MC) on urea(left), and copolarization of urea & pyruvate(right).

Urea-only	SNR increase with MC	Control group ratio
1	1.66	1.04
2	2.12	1.08
3	1.99	1.06
4	1.82	0.98

Copola rization	SNR increase w/ MC	
	Urea	Pyruvate
1	2.13	1.09
2	2.08	1.18
3	1.64	0.88
4	2.08	1.12
5	1.62	0.99

Table 2. Relative measurement results to test the function of the device on urea(left) and copolarization of urea and pyruvate(right).

Conclusion A magnetic carrier was designed and built to supply suitable and safe magneticfield (> 50 G) to preserve the polarization during sample transfer, especially for hyperpolarized urea. In comparitive testing, this device demonstrated SNR improvements of approximately 2 fold for ^{13}C-urea while maintaining HP pyruvate SNR.

References [1] Chiavazza, Enrico, et al. JMR 227:35-38 (2012). [2] G. D. Reed, et al. IEEE Trans Med Imaging (2013).

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