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Adapting a 3T clinical MRI scanner for mouse brain hyperpolarized ^{13}C MR imaging

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Introduction

We present a robust and simple setup for rodent imaging with hyperpolarized metabolic contrast agents (HMCAs) in a clinical 3T MRI scanner (GE SIGNA™ Premier). The setup extends the use of pre-existing equipment to rodents, making it possible to test methods and hypotheses in vivo before moving to larger animals or humans. The usefulness of the setup is demonstrated by imaging the brain metabolism of hyperpolarized (HP) [1-^{13}C]pyruvate in a transgenic mouse model of Alzheimer's disease weighing as little as 17g in a wide-bore clinical MRI.

Methods

The system was designed with consideration of the following guidelines: The routine use of the scanner cannot be impeded thus the rodent system must be completely portable. The system should be useful for both mice and rat imaging using dedicated RF coils. A 3D-printed animal cradle was modified from [1] using free online software (tinkerCAD) and fabricated in-house via 3D printing. For minimal motion artefacts and optimal brain imaging, a mouse/rat head fixation system with delivery of anesthetic gas was designed, and heating was required to maintain animal body temperature. For the rapid and reliable injection of HCMAs for the ^{13}C imaging, free access to an i.v. catheter was incorporated. [1-^{13}C]pyruvate was hyperpolarized using a SpinAligner polarizer.

Results/Discussion

The general setup of a mouse inside the custom-designed cradle to enable MRI and HP 13C MRI in a 3T GE scanner is seen in Figure 1A. Circulating hot water supplies heating to the bed, and tooth and ear bars provide head fixation. HMCAs are delivered through a 26G BD Neoflon tail vein catheter. A 20mm ^{13}C surface loop coil was placed on the mouse head for ^{13}C detection (Fig 1B).

Proton images were acquired using the scanner body coil (T_2W FSE, TE/TR = 102.272/3000 ms, mtx=256x256x4, slice thickness 5mm). Image quality was sufficient for planning the hyperpolarized ^{13}C acquisition (Fig 2A). Post HP pyruvate bolus (150ul 40mM [1-^{13}C]pyr), dynamic spectral-spatial ^{13}C images were acquired within a 15mm coronal slice centered on the brain with FOV=20mm. TR=1s mtx=20x20 for pyruvate and lactate. For bicarbonate TR=2s and mtx=10x10. Flip angles were 10, 15, and

40 degrees, respectively. HP pyruvate and metabolites lactate and bicarbonate were readily detected (Fig 2B, C).

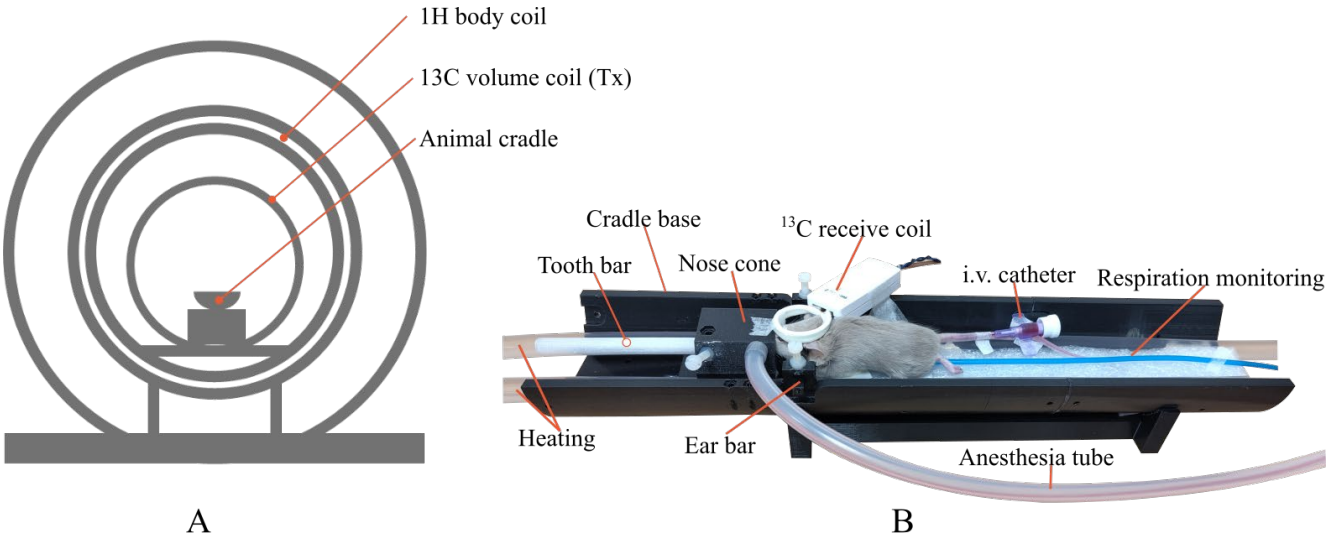

Fig. 1 - Physical setup. (A): Illustration of coil placements. (B): Rodent cradle setup with mouse.

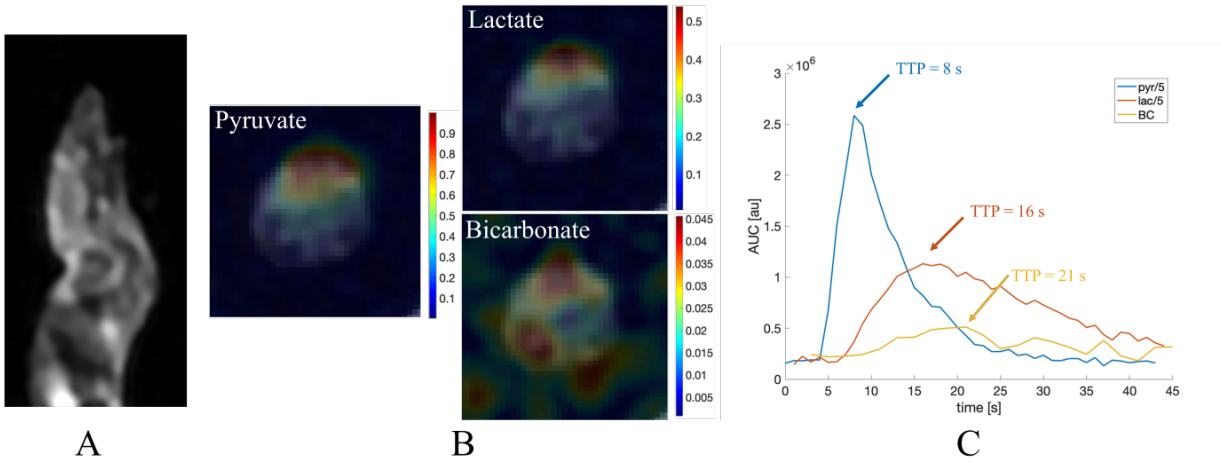

Fig. 2 – Representative mouse data. (A): Anatomical T2W ^{1}H MRI of the mouse acquired using the existing body coil. (B): Overlays of pyruvate, lactate, and bicarbonate images on the brain at their respective peak time. (C): Time course of the area under the curve (AUC) for each metabolite, summed over the entire brain, showing the time-to-peak (TTP). Lactate and pyruvate have been scaled down to show bicarbonate signal.

Conclusion

The setup presented here can extend the use of clinical MRI scanners to include small animals, while providing enough sensitivity to detect the production of both lactate and bicarbonate from a hyperpolarized [1-^{13}C]pyruvate bolus. As small animal imaging can provide guidance while planning a human or large animal study, this system provides the opportunity to test methods and hypotheses in rodents while using clinical equipment.

Novelty

A simple setup for rodent imaging in a clinical MRI which still provides enough sensitivity to detect 2 pyruvate metabolites

Impact

This system provides the opportunity to test methods and hypotheses in rodents while using clinical equipment, thus facilitating their translation.

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