

Preliminary results of metabolic MRI technology and PET in a patient with liver metastases

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Purpose

To demonstrate the feasibility of Deuterium Metabolic Imaging (DMI) and Phosphorus-31 (³¹P) Magnetic Resonance Spectroscopic Imaging (MRSI) for intrahepatic tumor detection.

Introduction

- Metabolic MRI can reveal simultaneous detection of multiple metabolites involved in cell proliferation and energy metabolism without the need of radio-isotopes, however, so far not available throughout the human body.

Methods

- We designed a metabolic body MRI system using a double-tuned RF bore transmitter for uniform excitation of ²H and ³¹P spins, an 8-channel ¹H dipole transceiver, and 8 dual-tuned receiver loops for ²H and ³¹P at 7T (Figure 1).
- After careful assessment of the system and safety performance, a 76-year-old patient with liver metastases from rectal carcinoma was enrolled to investigate altered metabolism before and after selective internal radiation therapy (SIRT) compared to healthy controls [1] and compared to FDG-PET/CT.
- The patient drank a deuterium-labeled glucose solution (20 grams of deuterated glucose dissolved in 100ml water) 40 minutes prior to the ¹H-²H-³¹P MRI exam of 60 minutes [2].



Figure 1. The schematic overview of the metabolic MRI setup (left) including the embedded double-tuned body transmitter (middle) and the wrap-around transceiver and receiver array for ¹H, ²H and ³¹P MRI.

Results

- We were able to see full metabolic maps throughout the liver (and a large part of the body) for both ²H, as well as ³¹P MR signals (Figure 2,4) at excellent signal to noise ratio.
- While no deuterated lactate signals were observed in the normal appearing liver tissue (Fig. 2D), lactate signals could be clearly distinguished in the metastasis with elevated SUV on the 18FDG-PET/CT scan before the start of SIRT (Fig. 2A). ³¹P MR spectra were remarkably similar between tumor tissue and normal appearing liver tissue (Fig. 2B,E), and substantial elevations of PME/PDE were observed throughout the whole liver compared to a healthy control, with the highest values in the metastatic region (Fig. 3A,B).
- One month after SIRT, deuterated lactate signals could no longer be detected in the metastasis (Fig. 4A), matching the decreased SUV uptake on the 18FDG-PET/CT scan. At the same time, a reduction in SNR was seen in the ³¹P MR spectra in the liver metastasis compared to pre-treatment, resulting in a near absence of ³¹P signal (Fig. 4B). The PME/PDE metabolic map after SIRT showed lower values than pre-treatment, but still much higher compared to healthy liver (Fig. 3C). In the normal appearing liver tissue, both ²H and ³¹P MR spectra were similar before and after SIRT (Fig. 4C,D).

References:

- Van den Wildenburg et al. NMR Biomed. 2023 May;36(5)
- Nam et al. Magn Reson Med. 2023 Sep;90(3):863-874

Results

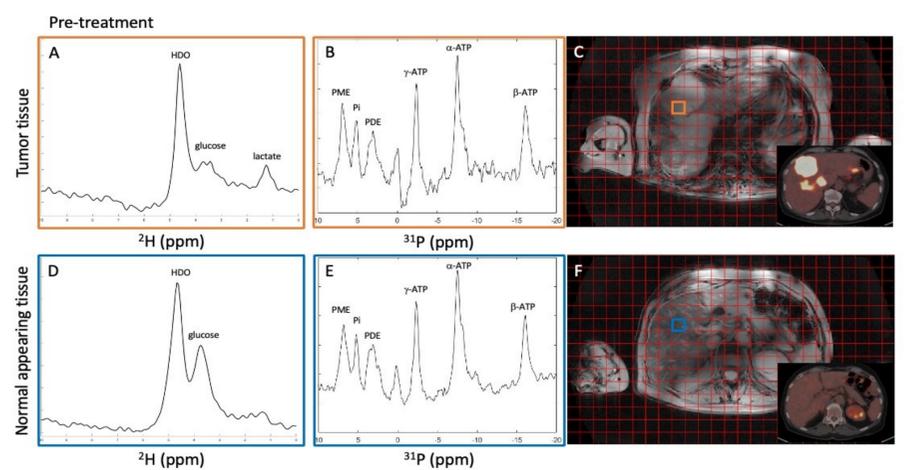


Figure 2. 3D ²H and ³¹P MRSI data obtained pre-treatment. ²H (A,D) and ³¹P (B,E) MR spectra are shown for a voxel in the metastasis (orange) and normal appearing liver tissue (blue). The voxel positions are indicated on the MRSI grid, overlaid on the anatomical scans (C,F). The corresponding 18FDG-PET/CT images are shown as insets. HDO, deuterated water; PME, phosphomonoesters; Pi, inorganic phosphate; PDE, phosphodiester; ATP, adenosine triphosphate.

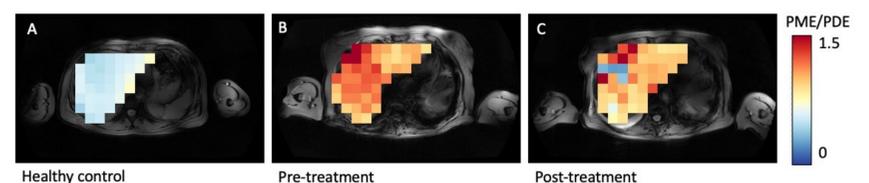


Figure 3. Metabolic maps showing the PME/PDE ratio in a healthy control (A) and in the patient pre-treatment (B) versus one month post-treatment (C). The metabolic maps are approximately at the same height of the liver, corresponding to the slice with the metastasis in the patient (Figure 2C,4C).

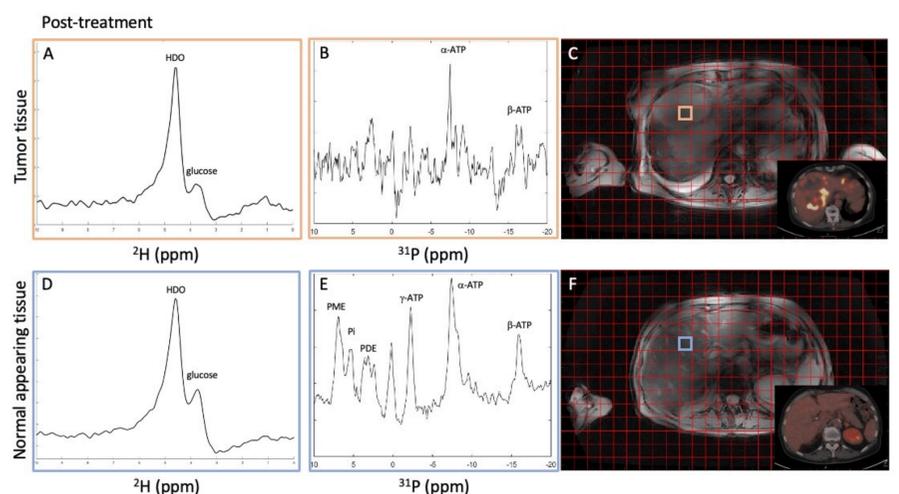


Figure 4. 3D ²H and ³¹P MRSI data obtained one month post SIRT. ²H (A,D) and ³¹P (B,E) MR spectra are shown for a voxel in the metastasis (orange) and normal appearing liver tissue (blue), at the same locations as pre-treatment (Figure 2).

Discussion and Conclusions:

The first in man study of ²H and ³¹P metabolic MRI from a patient was shown. While only from one patient, PME/PDE and deuterated lactate levels were clearly elevated in the metastases compared to a healthy liver.

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