P38

CIBM Annual Symposium 2024

Forum Rolex Learning Center, EPFL, Lausanne Switzerland | 7th November 2024

20th Anniversary

Optimization of brain glucose and lactate measurement using ultrashort-TE STEAM at 7 T: feasibility and preliminary results

Ying Xiao[1,2,3], Bernard Lanz[1,2], André Döring[1,2], Lijing Xin[1,2]

1. CIBM Center for Biomedical Imaging, Switzerland; 2. Animal Imaging and Technology, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland; 3. Laboratory for Functional and Metabolic Imaging (LIFMET), Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Background

- **Glucose** is the primary energy source for cerebral metabolism in healthy humans[1].
- **^{13}C metabolic modeling input function**: Using ^{13}C MRS combined with ^{13}C-labeled glucose administration is a powerful tool to estimate metabolic fluxes, such as TCA cycle flux. Metabolic modeling requires input functions such as brain glucose isotopic enrichment.
- **Lactate** can also provide valuable information regarding glycolysis[2].

Challenge

Measuring the temporal evolution of glucose and lactate concentration from ^{1}H MR spectra is very challenging due to:

- **Low concentration** of glucose in brain tissues
- **Glucose spectra overlap with water** and high-concentration metabolites like choline at 3-4 ppm[3]
- **Lactate overlaps with macromolecules**

Purpose

Optimized and evaluated ultrashort-TE STEAM[4] sequences with and without the inversion recovery for **detecting brain glucose and lactate levels at 7 T**

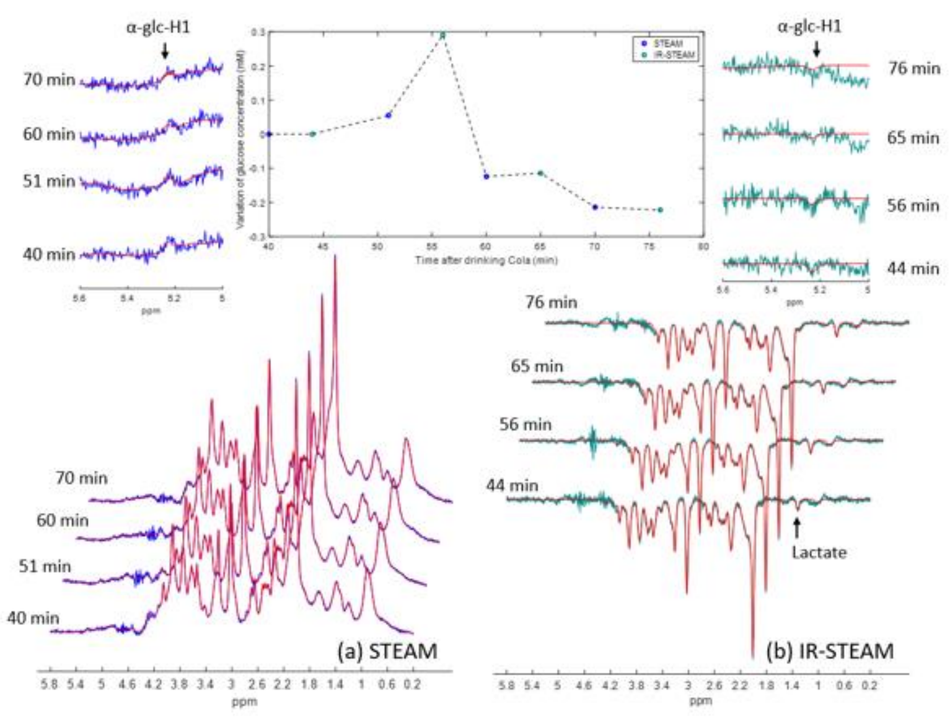


Figure 3: Variation of glucose concentration over the time measured with (a) STEAM (64 averages per measurement, VOI = 3x3x3 cm^3) and (b) IR-STEAM (TI = 260 ms, other parameters same as (a)).

Conclusion

This study successfully optimized and validated the use of STEAM and IR-STEAM sequences for detecting brain glucose and lactate levels at 7 T, offering a powerful tool for total brain glucose and lactate concentration measurement. The methods developed provide a reliable approach combined with ^{13}C MRS to study cerebral glucose metabolism, with potential applications in clinical practice.

Method

Material:

- 7T TerraX scanner (Siemens Healthineers, Erlangen, Germany)
- 8-channel transmit/32-channel receive coil array (Nova Medical, Inc. Wilmington MA, USA)

Volunteer preparation:

- 3 healthy volunteers (females, aged 29-44)
- Drink a bottle of sweet beverage (around 22 g glucose in total) before scanning

In vivo protocol:

- MP2RAGE[5] with a 3x3x3 cm^3 voxel above the corpus callosum in the middle of the brain
- Two ^{1}H MR sequences:
  - (1) STEAM
    - TE/TM/TR = 4.5/25/4000 ms
    - Interleaved OVS + VAPOR
    - 32-step phase cycling
  - (2) STEAM with inversion recovery (IR-STEAM)
    - Adiabatic HS4 pulse (duration = 5.12 ms bandwidth = 4 kHz)

Data processing:

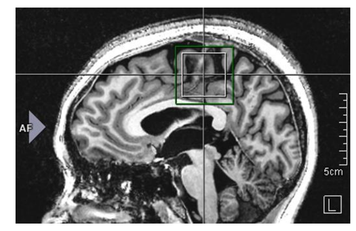
- Coil combination
- Frequency alignment
- HSVD water removal[6]
- Quantified using LCModel[7] over a range from 0.2 ppm to 6.0 ppm
- T_1 relaxation correction[8].

Result

- Feasibility and efficiency:
  - Measuring the α-glc-H1 (36% natural abundance) resonance at 5.23 ppm is possible
  - With the fine-tuned water suppression scheme and HSVD applied, the remaining water residuals were removed efficiently (Figure 1)
- TI optimization:
  - Minimized the macromolecules overlapping with lactate with TI from 220 ms to 280 ms (Figure 2)
- Dynamic detection:
  - The variation of the brain glucose concentration was measured using both sequences (Figure 3)
  - STEAM has double SNR but similar CRLB with IR-STEAM

Discussion

- **Feasible at 7T**: Using both STEAM and IR-STEAM sequences, combined with optimized water suppression, to measure the α-glc-H1 and lactate in the human brain
- **Fine-tuning the water suppression** pulse delay and using HSVD in post-processing is crucial for reliable glucose detection and quantification.
- **IR-STEAM suppresses the MM overlapping with lactate** for the precise measurement of lactate avoiding the effect of a mismatched MM basis.
- **Potential to detect ^{13}C-coupled ^{1}H satellites for both glucose and lactate:** the direct determination of fractional enrichment in the brain without the need for blood samples.



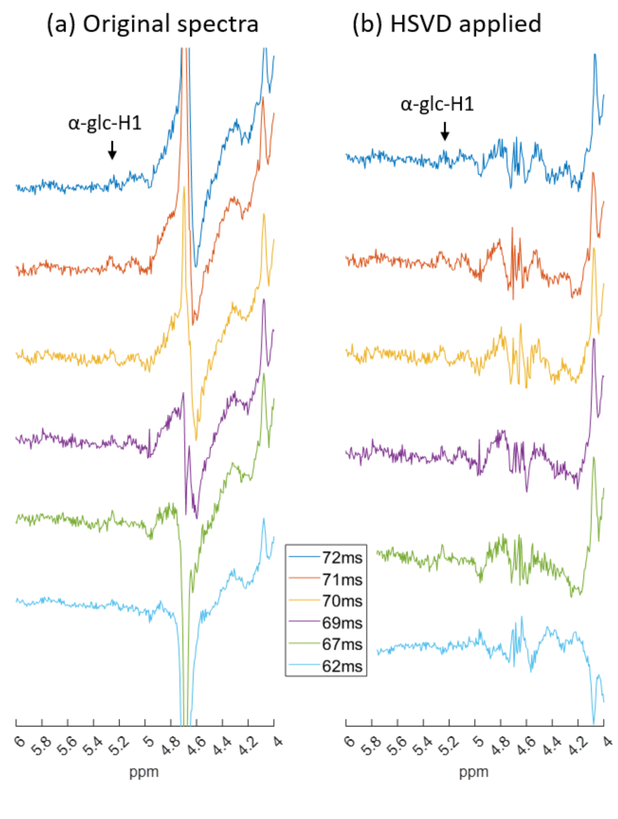


Figure 1: Fine-tuning the last water suppression pulse delay of VAPOR: (a) Original spectra acquired with STEAM (32 averages, VOI = 3x3x3 cm^3); (b) Spectra with water residuals removed.

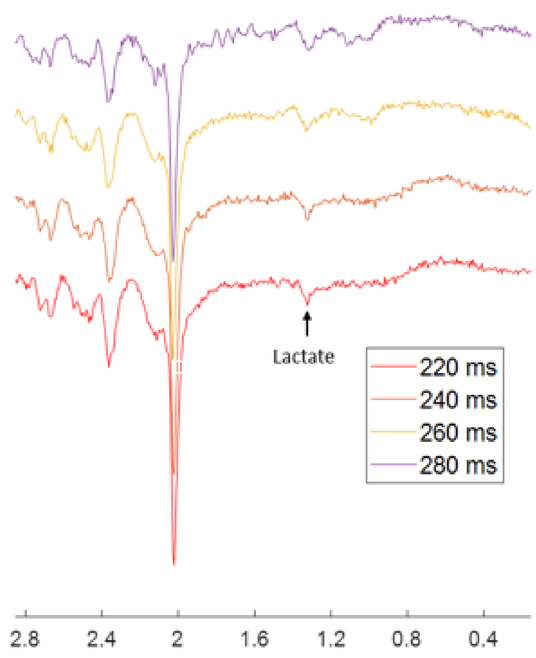


Figure 2: Fine-tuning the inversion time (TI) from 220 ms to 280 ms. The lactate peak at 1.3 ppm is clearly separated from the MM resonances.

Reference

1.Dienel (2019). 2. Rodrigues et al. (2013). 3. Kaiser et al. (2016). 4.Tkáč et al. (2001). 5. Marques et al. (2010). 6.Barkhuijsen et al. (1987). 7.Provencher (2001). 8.Xin et al. (2013).

This work was supported by the Swiss National Science Foundation (grants n° 320030_189064). We acknowledge access to the facilities and expertise of the CIBM Center for Biomedical Imaging, a Swiss research center of excellence funded and supported by Lausanne University Hospital (CHUV), University of Lausanne (UNIL), Ecole Polytechnique Fédérale de Lausanne (EPFL), University of Geneva (UNIGE) and Geneva University Hospitals (HUG). We also acknowledge the facilities and expertise provided by Fondation Campus Biotech Geneva (FCBG) during this study.