GluCEST: High Resolution Imaging of Glutamate

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Outline

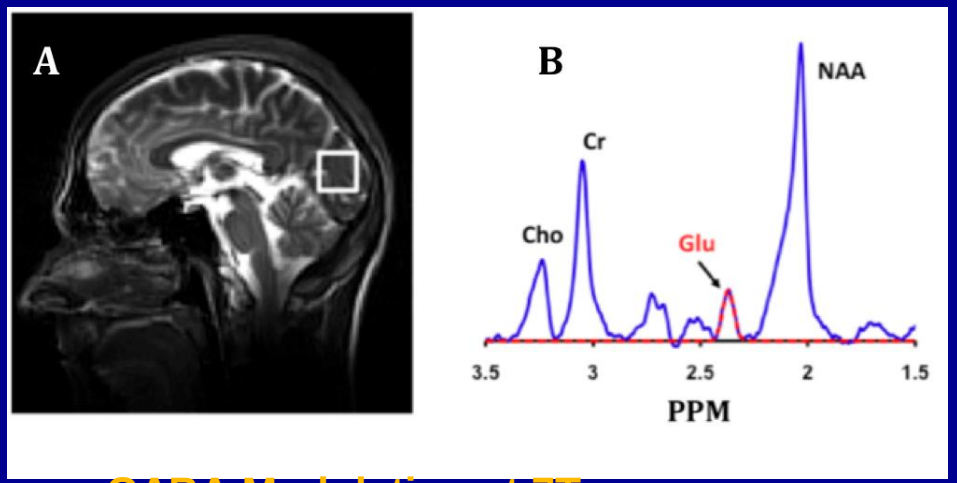
- MRS of tDCS
  - Excitatory (anodal) stimulation
  - Inhibitory (cathodal) stimulation
  - MRS results
- Imaging of Glutamate and GABA
  - CEST of Glu, and GABA
    - characterization of GluCEST
    - pH dependence of GluCEST in MCAO model
    - In vivo GluCEST from human brain at 7T
- Sodium Imaging at 7T
  - Potential for intra and extracellular Na changes

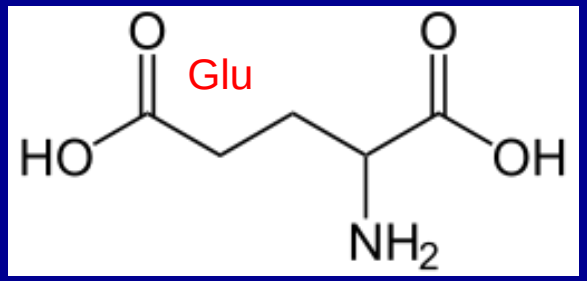
Glutamate and GABA

- Glutamate is the major excitatory neurotransmitter
- GABA is an inhibitory neurotransmitter
- MRS methods are capable of quantifying GABA and Glutamate
  - Low spatial resolution (8 to 27 cc volume) and long acquisition times

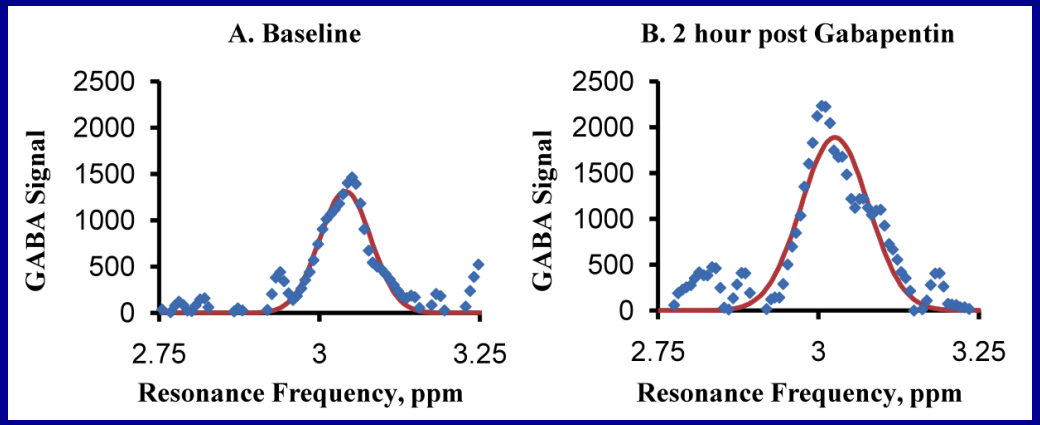
[1] Petroff, O.A. Neuroscientist 8, 562-573 (2002). [2]. Harrison, P.J. Br J Psychiatry 192, 86-87 (2008). [3] Rothman, D.L., et al. PNAS USA 90, (1993). [4] Ryner, L.N., et al,. JMR B 107, 126-137 (1995).

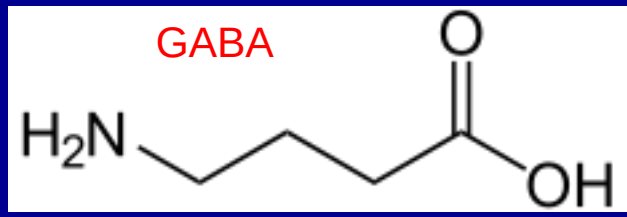
MRS at 7T





GABA Modulation at 7T





Transcranial Direct Current Stimulation (tDCS) and MRS

5202 • The Journal of Neuroscience, April 22, 2009 • 29(16):5202–5206

Brief Communications

Polarity-Sensitive Modulation of Cortical Neurotransmitters by Transcranial Stimulation

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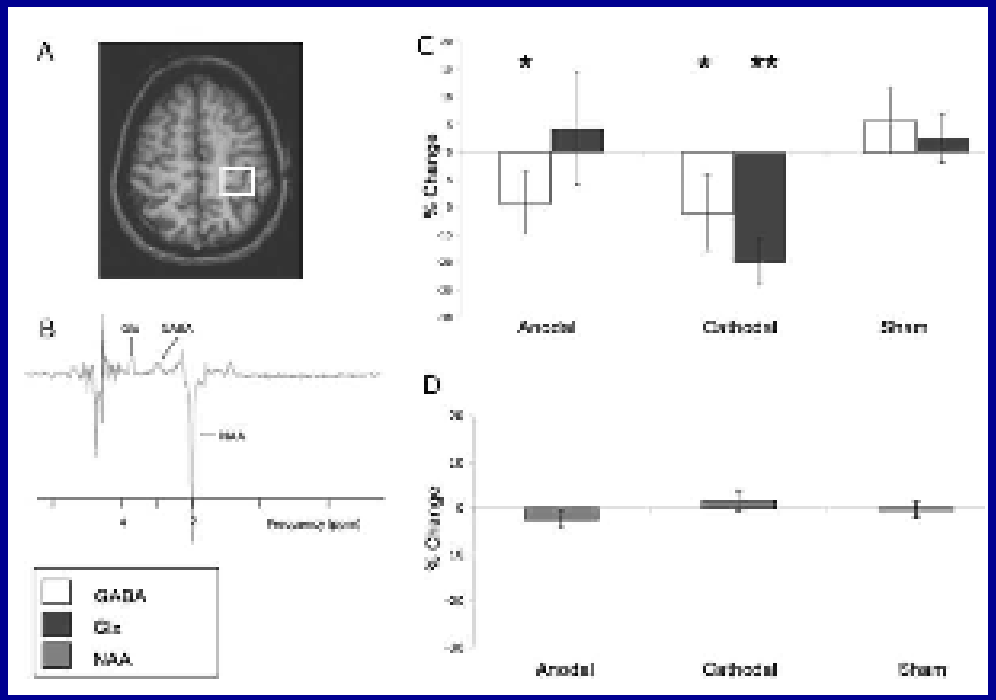
MRS of tDCS



Charlotte J. Stagg,

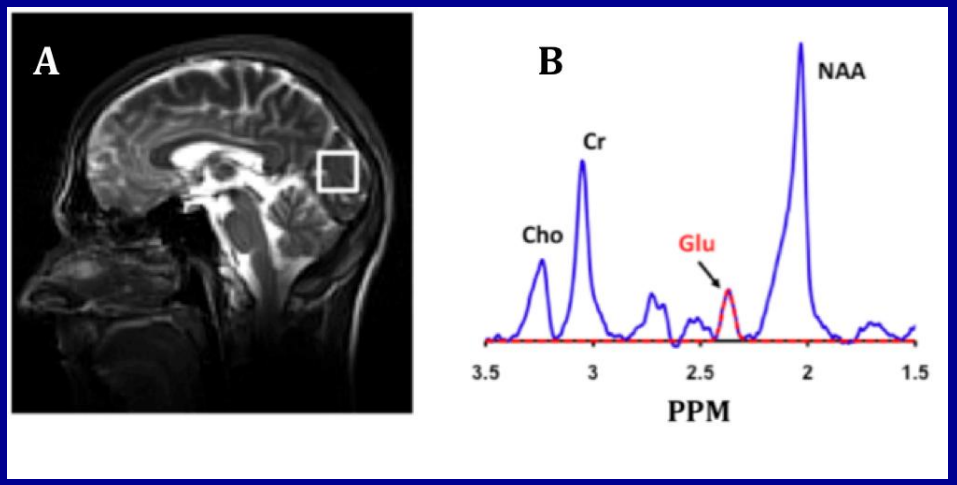
J. Neurosci., April 22, 2009 • 29(16):5202–5206 • 5203

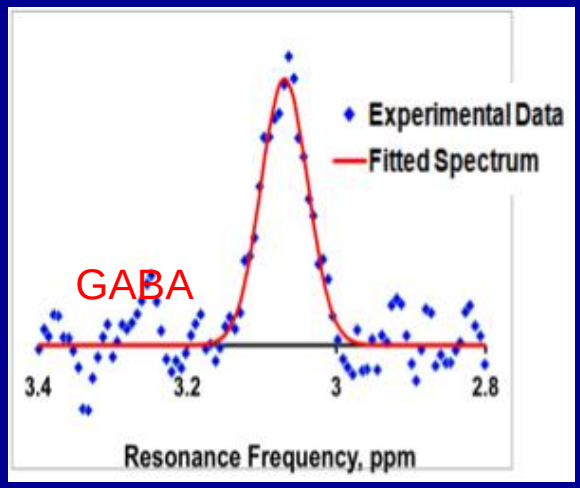
- A, Typical placement of the 2 x 2 x 2 cm voxel within the left sensorimotor cortex. B, GABA optimized 3 T spectrum, showing resonances from NAA, GABA, and Glx. C, Changes in neurotransmitter-to-NAA ratios, given as percentage change from baseline values (mean ± SD). *p < 0.05, **p < 0.01. D, No change in absolute NAA quantification is seen in any stimulus condition. E, F, The decreases seen in both GABA (E) and Glx (F) following stimulation were sustained over the 20 min scanning period.

Imaging of brain neurotransmitters

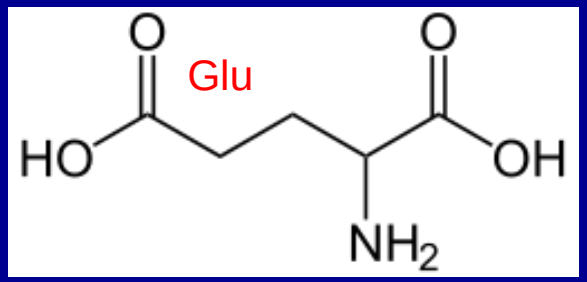
- PET
- SPECT
- MRI

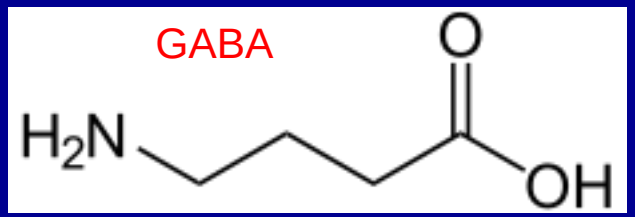
MRS at 7T





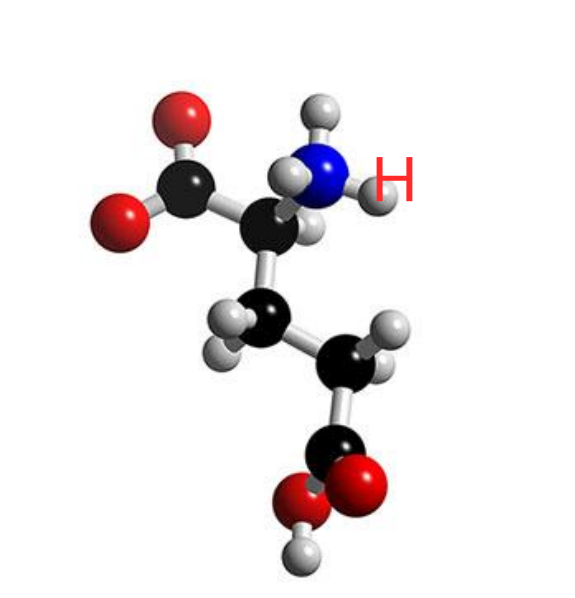
- *Figure 1. A. T_2 weighted MRI with occipital region of interest is identified with a square box. B. Localized single voxel spectrum from brain of a healthy volunteer (occipital region identified with square box in the image). Glu -CH_2 resonance is indicated with an arrow.*





Chemical Exchange Saturation Transfer (CEST)

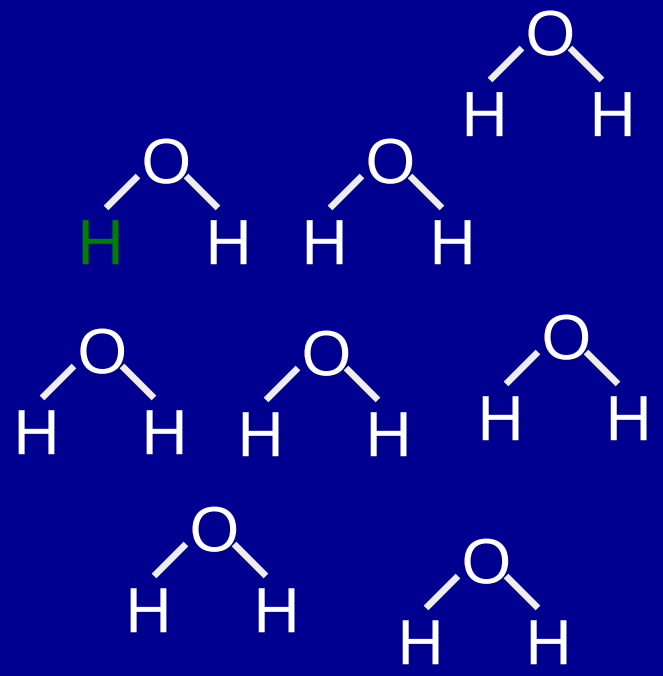
Solute Pool



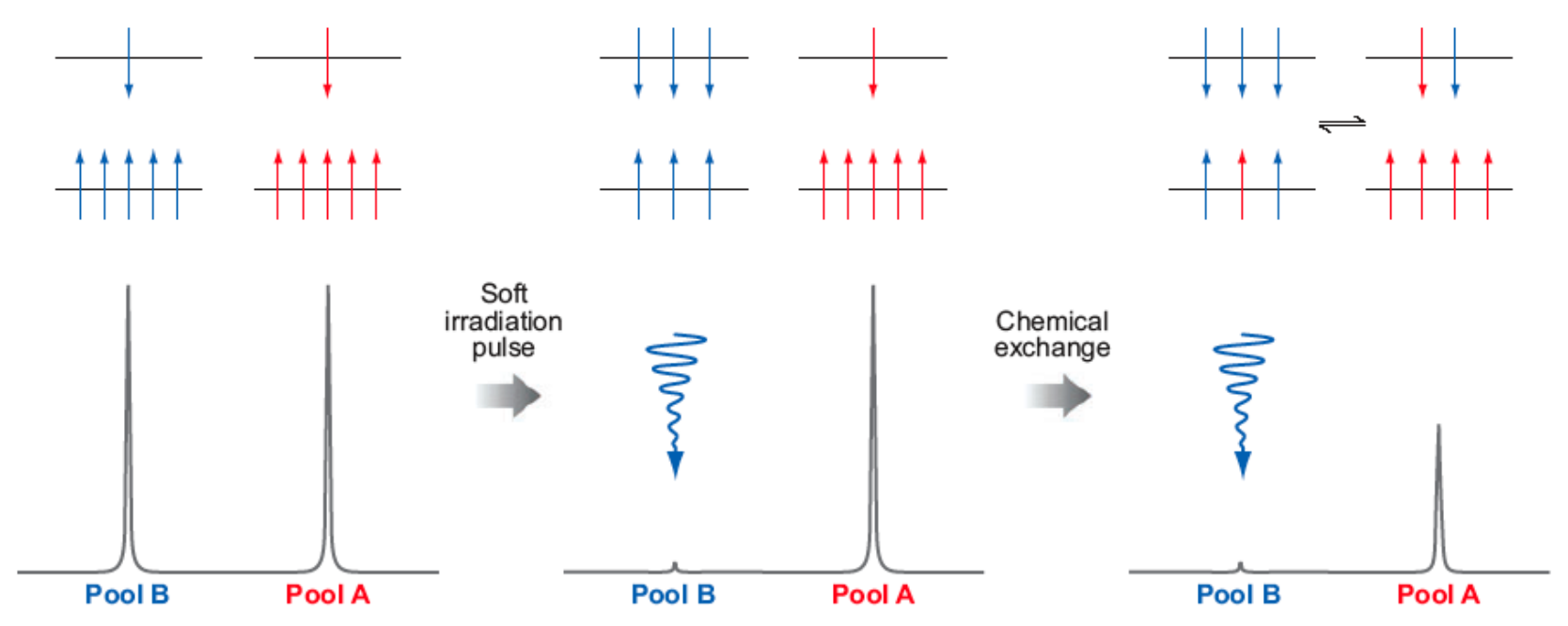
k_{sw}

k_{ws}

Water Pool



Chemical Exchange Saturation Transfer



Steady State Magnetization

- Direct saturation
- CEST Asymmetry
- Saturation efficiency and Exchange rate constant
- Conc. Of CEST agent

$$\frac{M_{A\infty}}{M_{A0}} \approx \frac{1}{(1+k_1 T_{1w})}$$

$$CEST_{asym}(\Delta\omega) = \frac{M_{sat}(-\Delta\omega) - M_{sat}(\Delta\omega)}{M_0}$$

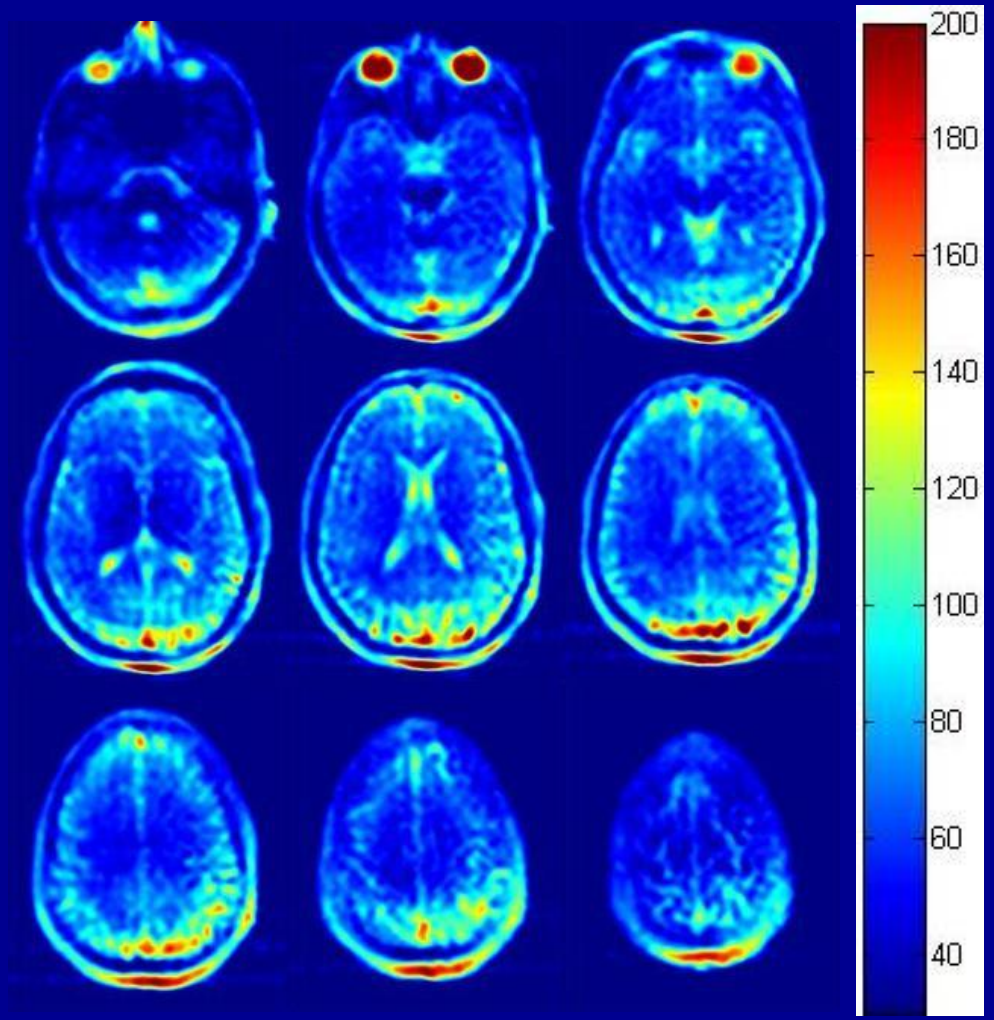
$$CEST_{asym}(\Delta\omega) = \frac{k.\alpha.f}{R_{1w} + k.f}[1 - e^{-(R_{1w}+k.f)t_{sat}}]$$

Experimental Considerations

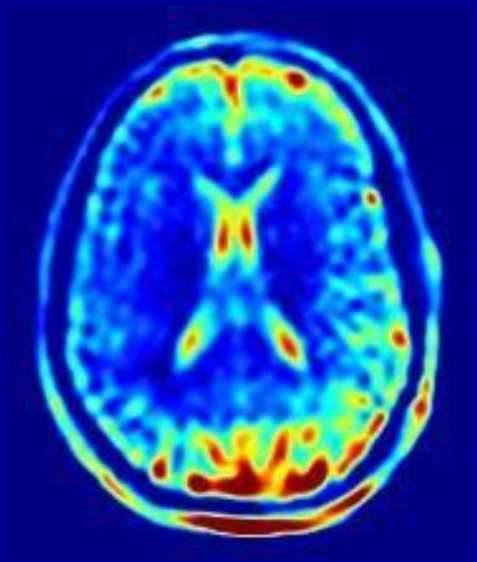
- **GluCEST depends**
  - pH and concentration
  - Pulse sequence parameters –
    - saturation pulse shape, amplitude (B1), and duration
  - Static field strength (Bo)
- **Bo and B1 inhomogeneity correction is essential**

SNR Map of ^{23}Na Head Images at 7T with 12 Channel Phased-Array Coil

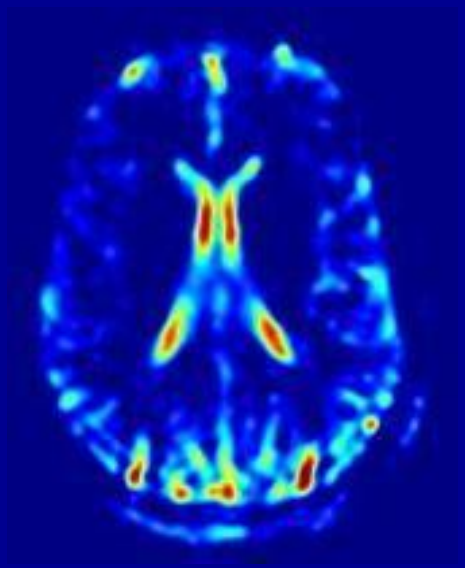
4x4x12 mm
TE: 550 µs, TR: 30 ms
30 averages
Acquisition time: 22 min
Spoiled gradient half-echo with acquisition-weighted half-Fourier readout



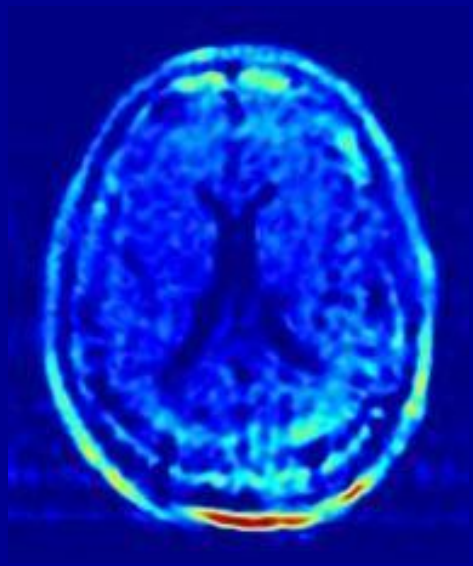
Sodium MRI at 7 Tesla: Total Sodium Concentration Imaging with Long T_2^* (Fluid) Suppression



Total Sodium Concentration
TE: 600 µs



Heavily T_2^*-weighted
TE: 23 ms



Difference Image: Fluid Suppression

12 channel sodium RF coil from MR solutions
Siemens UTE WIP

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