Brain bioenergetic changes caused by transcranial direct current stimulation; a ^{31}P MRS study

C. Rae[1], V. Lee[2], C. Loo[3], and R. Ordidge[4]
[1]Neuroscience Research Australia, Randwick, NSW, Australia, [2]School of Medical Sciences, The University of New South Wales, NSW, Australia, [3]School of Psychiatry, The University of New South Wales, Australia, [4]Dept of Medical Physics, University College London, United Kingdom

Introduction

Transcranial direct cortical stimulation (DCS) is a novel treatment for a range of brain disorders. It may work by altering brain activity (Nitsche et al. 2008) although the mechanism for this is not clear. Here, we used ^{31}P MRS to investigate whether brain bioenergetics were altered by tDCS, and on what timeframe.

Methods

We studied 9 healthy young controls (4 males, range 19 - 28 y) using a blinded, pseudo-randomised, cross-over design. All MR was acquired at 3T (Philips Achieva TX) using a 10 cm ^{31}P surface coil (Pulseteq). tDCS was delivered with a 3T compatible tDCS machine (NeuroConn). Subjects were fitted with electrodes (anode on left DLPFC, cathode on right orbitofrontal secured with a rubber band). ^{31}P spectra were acquired (pulse (sech) and collect, TR = 2s, NS = 16) before stimulation (5 spectra), during stimulation (1 mA for 10 min (active) or for 30s (sham), 15 spectra) and immediately following stimulation (40 spectra). Subjects returned at the same time of day at least 2 days later for the cross-over session. Spectra were processed using jMRUI (v 3) using the AMARES algorithm with minimal linewidth constraints on Pi and PDE (Fig. 1) and weighting of the FID. Metabolites are expressed relative to the fiducial PPA resonance.

Fig. 1. Example AMARES fit

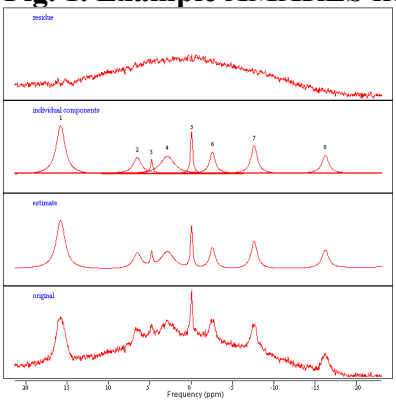


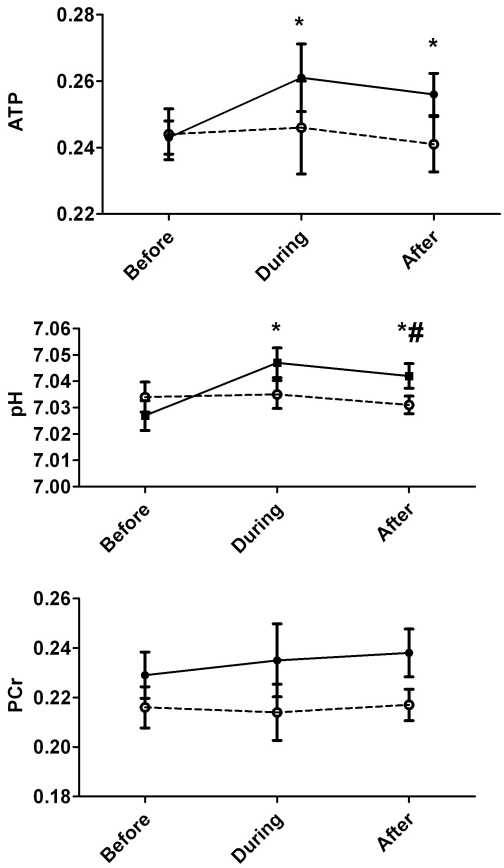
Table 1. ^{31}P Metabolite levels relative to PPA

* significantly different to "before", # significantly different to "during".

Metabolite	Before	During	After
Pi - Sham	0.073 (0.011)	0.070 (0.011)	0.069 (0.010)
Pi - Active	0.077 (0.007)	**0.070** (0.011)*	**0.069** (0.009)*
PCr - Sham	0.216 (0.025)	0.217 (0.029)	0.218 (0.030)
PCr - Active	0.229 (0.028)	0.235 (0.039)	**0.238** (0.029)*
β-ATP - Sham	0.244 (0.023)	0.246 (0.037)	0.245 (0.036)
β-ATP -Active	0.243 (0.015)	**0.261** (0.027)*	**0.256** (0.019)*
pH - Sham	7.034 (0.017)	7.035 (0.014)	7.031 (0.010)
pH - ACTIVE	7.027 (0.017)	**7.047** (0.015)*	**7.037** (0.013)*#
PDE - Sham	0.498 (0.059)	0.483 (0.057)	0.483 (0.054)
PDE - Active	0.515 (0.065)	0.486 (0.070)	0.506 (0.055)

Results Levels of ATP and brain pH increased during stimulation, while inorganic phosphate (Pi) decreased. Following stimulation, levels of PCr increased (and continued to rise), while levels of ATP and brain pH decreased but remained elevated compared to control. There was no significant change in PDE.

Fig. 2. Changes in ATP, pH and PCr with tDCS vs sham. Errors = SEM



Discussion

We found acute changes in the level of brain high energy phosphate compounds following tDCS, occurring rapidly after initiation of stimulation. Intracellular pH, one of the most accurate parameters that can be measured by ^{31}P MRS, and the high energy currency ATP are elevated during tDCS, while the increase in PCr continues to occur after tDCS is ceased. The mismatch between PCr changes and pH suggests that compartments other than the creatine kinase catalysed reaction may be involved.

References

Nitsche MA, et al. 2008. Brain Stimulation 1:206-23.