The neurochemistry of cortical auditory processing: insights from magnetic resonance spectroscopy and magnetoencephalography

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Introduction

The electrophysiology of cortical auditory processing has been characterized in numerous studies (1). Its neurochemical basis, in contrast, is largely unknown. We combined magnetoencephalography (MEG) and proton magnetic resonance spectroscopy (1H-MRS) to assess the relationship between the electrophysiology and the neurochemistry of the left auditory cortex. MEG has a good spatial and a supreme temporal resolution. MRS allows to quantify the concentrations of specific molecules within defined regions in the brain (2) We tested the hypothesis that a) the strength of the N1 deflection, the major component of the long-latency auditory evoked responses and b) the decrement of this response during rapid stimulation are correlated with the neurochemical parameters of neuronal and synaptic function as assessed by proton MRS.

Methods

15 healthy volunteers (age, 18-68 years; 6 females, 1 left-handed). T1-, T2-, and proton density-weighted were performed on a 1.5 T scanner (Magnetom SP, Siemens, Erlangen, Germany). A single voxel STEAM (stimulated echo acquisition mode) spectroscopy was acquired (TE = 20 ms, TR = 2.5 s, number of scans = 128) (3). The MRS voxel (1.5 x 1.5 x 1.5 cm^3) was centered at the left transverse gyrus of Heschl (Figure 1). For the postprocessing of MRS spectra, a time domain fitting program (LC model) was used. Data were expressed in institutional units (IU). Auditory evoked magnetic fields were recorded with a 37-channel biomagnetic system (Magnes I, BTi, San Diego, USA). Short sequences of 4 identical, rapidly recurring speech (the vowel /a/) and non-speech sounds (a corresponding sine tone) served as stimuli. Subjects listened passively to 160 trials of each sequence in randomized order. The source location of the N1 response was assessed employing the model of a single equivalent dipole. The source waveform (a spatio-temporal dipole fit) was calculated. The amplitude of the 1st N1 peak and the amplitude decrement (relative source strength of the 2nd response compared to the 1st) were determined.

Results

The source strength of the auditory N1 peak was significantly correlated with the concentrations of N-acetylaspartate (NAA) (r=0.52; p=0.046; linear regression analysis; Figure 2) and choline containing compunds (Cho) (r=0.35; p=0.020; Figure 3). In addition, glutamate/glutamine (Glx) and the relative source strength of the 2nd N1 response were significantly correlated (r=0.55; p=0.033; Figure 4).

Discussion

The combined use of MEG and 1H-MRS suggests that the processing of auditory stimuli depends on the density and functional integrity of neurons and cell membranes in the auditory cortex, as reflected by the concentrations of NAA and Cho. The amino acid NAA is synthesized predominantly in neurons and is regarded as a neuronal marker in 1H-MRS. As precursors or degradation products of membrane phospholipids make a major contribution to the Cho signal, Cho is regared as a membrane marker. In addition, processing of rapid auditory stimulus sequences (important, e.g., for speech comprehension) is based, at least in part, on excitatory neurotransmission, represented by the concentration of glutamate/glutamine. The present study, the first to combine the assessment of brain metabolism via MRS and the recording of evoked responses via MEG, stresses the potential of this approach for an advanced understanding of the physiology and pathophysiology of human brain functions.

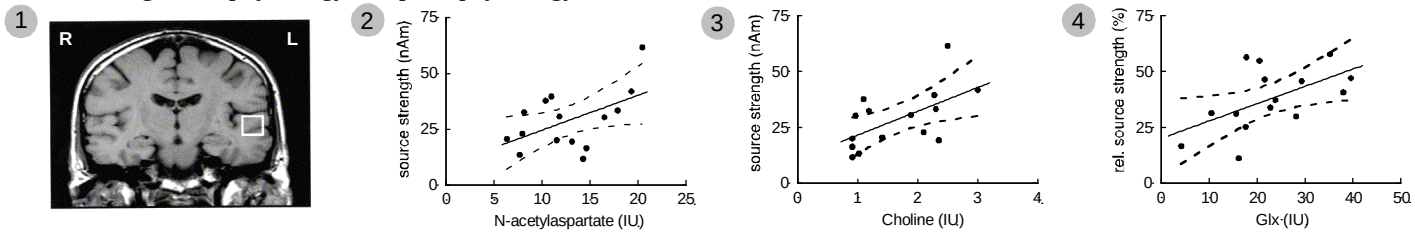

Fig.1: Location of the 1H-MRS voxel in the left auditory cortex. Fig. 2: Linear regression plot of source strength as a function of NAA (regression plot; dashed lines, 95% confidence interval). Fig. 3: Source strength as a function of Cho. Fig. 3: Relative source strength as a function of Glx.

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