Improved PRESS sequence for lactate detection in the human vitreous body

E. Balteau[1], N. J. Collignon[2], P. A. Robe[3], V. Sterpenich[1], G. Llabrès[4], A. Luxen[1], P. Maquet[1]

[1]Cyclotron Research Centre, Liège University, Liège, Liège, Belgium, [2]Department of Ophthalmology, University Hospital of Liège, Liège, Liège, Belgium, [3]Neurosurgery and Human Genetics, University Hospital of Liège, Liège, Liège, Belgium, [4]Department of Physics, Liège University, Liège, Liège, Belgium

Introduction

In clinical neuroscience, there is strong demand for methods allowing for the assessment of vitreous lactate levels in several ocular pathologies (e.g. glaucoma, ischaemia). *In vivo* ^{1}H magnetic resonance spectroscopy (MRS) facilitates the non-invasive investigation of the vitreous metabolic composition. However, this application of MRS is particularly challenging in various respects. The vitreous body is located in a region which is highly affected by B_0 magnetic field inhomogeneities, and shimming over such a region is not straightforward, leading to poor water suppression. Moreover, the maximum size of the volume of interest (~1.0 mm³) reduces the signal-to-noise ratio. In addition, the vitreous body is surrounded by large amounts of periorbital fat which may contaminate the spectrum and overlap the lactate doublet. To our knowledge, only one study reported such measurements [1], but required long acquisition times, and lactate assignment only relied on the chemical shift value of the doublet. The method described in the present study employs improved shimming techniques and an improved MRS sequence for lactate detection in the vitreous body of healthy volunteers, with short acquisition times and reliable doublet assignment.

Methods

Experiments were performed on a 3.0 T *Allegra* scanner (Siemens, Erlangen, Germany). A modified version of the KIM *et al.* shimming procedure was implemented [2] and adapted in order to take into account hardware constraints and to reach satisfactory homogeneity even for small volumes of interest. The Siemens original single-voxel PRESS sequence was modified to include BASING water suppression [3], timing parameter flexibility, and editing scheme [4]. The BASING water suppression technique is advantageous due to its robustness to B_0 inhomogeneities and its lactate doublet refocusing ability. The Shinnar-le-Roux algorithm [5] was applied to design excitation and refocusing pulses with better frequency profiles, yielding better spatial localization. The PRESS sequence parameters were as follows : TR = 3000 ms, TE = 145 ms, NEX = 32, spectral bandwidth = 2000 Hz, 2048 data points. Two measurements were performed for spectral editing purposes for each of 6 healthy volunteers. Spectra were analyzed with the jMRUI software [6]. Taking advantage from the GAMMA C++ library [7], numerical simulations of the sequence were implemented to determine the optimal timing parameters and RF pulse specifications. *In vitro* and *in vivo* experiments were performed to assess the theoretical results.

Results and Discussion

The BASING pulses were positioned according to [8] with a slight delay taking into account the length of the pulse and its asymmetry, as determined by numerical simulations and confirmed by the experiment. Wrong positioning of the BASING pulses would lead to incomplete refocusing of the lactate doublet. The optimal parameters for the BASING pulses at 3.0 T were then fixed as follows, yielding both improved water suppression and lactate detection : pulse length = 21 ms, bandwidth = 260 Hz ; the reference time point for pulse positioning was set to 5.5 ms after the beginning of the pulse. The *J* coupling constant was found to be 6.9 Hz, in agreement with the literature. The frequency shift of the BASING carrier frequency for *J*-difference editing purpose was set to 97 Hz.

Figure 1 illustrates the result for a representative *in vivo* experiment. The lactate doublet is detected at 1.33 ppm in the vitreous body of a healthy volunteer. The shimming procedure was applied successfully, making it possible to reduce the linewidth to 18 Hz. Water suppression was efficient even with shifted BASING pulses, and lipid contamination was reliably discarded with the editing scheme, ensuring without ambiguity that the resonance occurring at 1.33 ppm was the lactate doublet. Except for lipids in 4 from the 6 volunteers, no other resonance was detected. The spectra were acquired within 3:30 minutes, which is convenient and manageable for a volunteer who is asked to keep their eyes fixed during the acquisition. In contrast, a previous study [1] required 20 minutes scan duration for the acquisition of a single spectrum, without editing scheme.

Conclusions

This study assesses the feasibility of ^{1}H-MRS lactate detection in the human vitreous body with short acquisition times and high reliability. The experiments benefit from various technical improvements in field homogeneity, water suppression, localization accuracy, and lactate edition. The method allows for further clinical applications as well as investigation of the dynamic aspect of lactate production. Application of the technique to a larger number of healthy volunteers and to patients with ophthalmic diseases is currently in progress.

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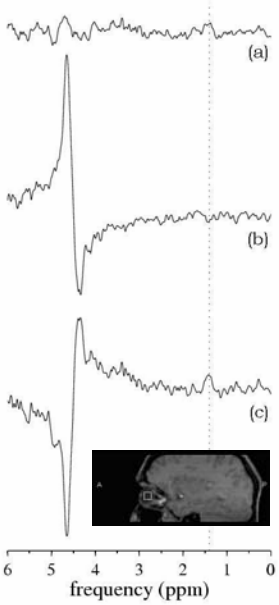

Fig. 1 – Location of the volume of interest and spectra from the *J*-difference editing scheme. The lactate doublet is clearly and reliably detected within 3:30 minutes of acquisition. (a) Lactate doublet refocused by the BASING pulses, (b) no lactate refocusing due to frequency shift of the BASING carrier frequency and (c) difference between (a) and (b).