Preliminary results of 31P MR imaging at 9.4T using a RARE sequence

A. Lu[1], I. C. Atkinson[1], X. J. Zhou[1], T. Claiborne[1], and K. R. Thulborn[1]
[1]Center for MR Research, Univ. of Illinois at Chicago, Chicago, IL, United States

INTRODUCTION

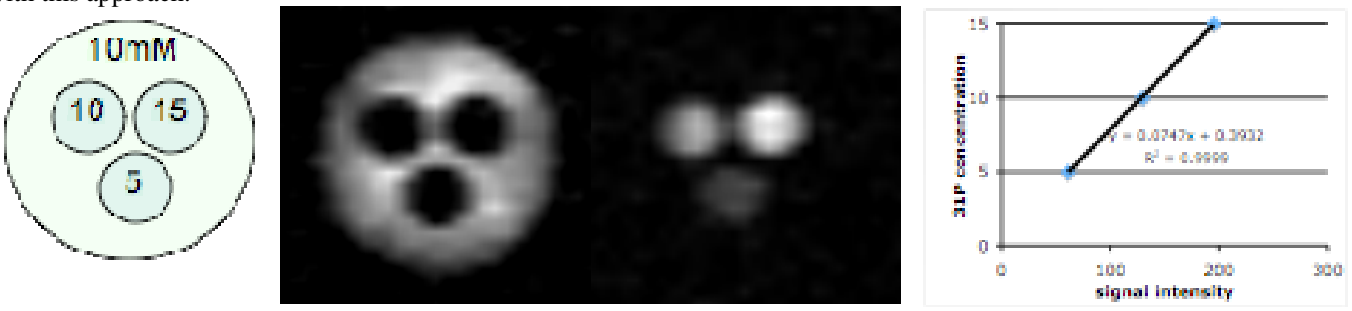
^{31}P MRS/I can provide quantitative bioenergetic information of human brain non-invasively [1-4]. However, quantitative determination of the spatial distribution of ^{31}P is challenging due to its low biological concentration and low gyromagnetic ratio. ^{31}P MR signals have been mainly studied with spectroscopy or chemical shift imaging approaches, which are time consuming and/or have limited spatial resolution. Fast imaging techniques such as RARE have been proposed for the quantification of ^{31}P signals in muscle [5], where the ^{31}P concentration is several fold higher than that in the brain tissue. The availability of a 9.4T human scanner provides new opportunities to increase the sensitivity of metabolic imaging based on specific phosphorous metabolite. In this work, we report initial results on a phantom with inorganic phosphorous (Pi) concentration comparable to that of PCR in the brain acquired within 10 minutes with 2.5mm^3 voxel size and demonstrate the potential of quantitative spectral selective 31P imaging at ultra high field.

MATERIALS AND METHODS

The experiments were performed on a 9.4T human scanner with an 80cm bore. A quadrature birdcage head coil was used for excitation and reception. The phantom was made to match the load of a human head and with concentration similar to that of PCr in human brain. As illustrated in Figure 1a, it consists of a sphere filled with 10 mM Na_3PO_4 solution and three cylinder tubes filled with 5 mM, 10 mM and 15 mM KH_2PO_4 solution, respectively. The chemical shift between the solution in the sphere and the tubes were ~3ppm. A spectrally selective excitation pulse was designed using a Shinnar-Le Roux algorithm with optimizations [6]. The pass-band (~200 Hz) of the pulse was tailored to match the spectral width of the selected peak. This pulse (pulse width =12 ms) was incorporated into a 3D RARE pulse sequence with an echo train length of 18 produced by a series of non-selective refocusing pulses (pulse width = 4ms). Acquisition parameters included a 32 cm X 32 cm X 20cm field of view and a 32 X 32 X 8 imaging matrix, giving an image resolution of 1 cm X 1 cm X 2.5 cm. A repetition time of 15 s was used to account for the long longitudinal relaxation time of 31P signal, and the effective TE was ~12 ms. Two sets of images were acquired with the pass-band centered on the Na_3PO_4 solution and the KH_2PO_4 solution, respectively. Six averages were used to collect each data set with a receiver bandwidth of 4 kHz and an acquisition time of 10 minutes.

RESULTS AND DISCUSSION

With the current pulse sequence parameters, the average SAR was 0.75 W and well below the FDA guideline (3.2 W/kg). Figure 1b and c were images acquired with the selection of the solution in the sphere and the three tubes, respectively. Good spectral selectivity has been achieved. The SNR in the 5mM, 10 mM and 15 mM tubes were about 17, 36, 55 respectively. Image blurring due to long readout echo train is noticed in the phase encoding direction. As shown in Figure 1d, the signal intensities in the three tubes demonstrate a linear relationship with the concentration. Quantitative ^{31}P concentration maps can therefore potentially be obtained with this approach.



(a) (b) (c) (d)

Figure. 1 (a) Illustration of the phantom. b) image of a center slice with the selection of the solution in the sphere. (b) image of the corresponding slice with the selection of the solution in the tubes. (d) The signal intensities in the three tubes are plotted against the 31P concentrations.

CONCLUSIONS

With the increased sensitivity at 9.4T, 31P images with reasonable SNR have been obtained on a phantom with concentration comparable to that of PCr in human brain within 10 minutes. The extension of these results to human brain may potentially enable us to obtain high quality quantitative PCr images in an acceptable acquisition time for studying brain metabolism. Future work will further optimize the sequence and validate its performance on a human brain.

REFERENCE

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