Lactate-discriminating Echo-planar Spectroscopic Imaging at 7 T

Y. Bito[1], K. Hirata[1], T. Shirai[1], Y. Yamamoto[2], Y. Soutome[1], T. Ebisu[3], M. Umeda[4], Y. Kawai[4], T. Higuchi[5], and C. Tanaka[5]

[1]Central Research Laboratory, Hitachi, Ltd., Kokubunji-shi, Tokyo, Japan, [2]Advanced Research Laboratory, Hitachi, Ltd., Kokubunji-shi, Tokyo, Japan, [3]Neurosurgery, Nantan General Hospital, Kyoto, Japan, [4]Medical Informatics, Meiji University of Oriental Medicine, Kyoto, Japan, [5]Neurosurgery, Meiji University of Oriental Medicine, Kyoto, Japan

Introduction

Imaging of lactate distributions provides useful information about anaerobic metabolism in tissues, which enables estimating hypoxic damage in ischemia or detecting hypoxic cancer cells. Lactate imaging usually uses the ^{1}H chemical shift to detect the lactate signal, but overlapping lipid signals sometimes make accurate evaluation of the lactate concentration difficult. A standard technique for discriminating lactate from lipid uses the difference between two TE measurements, such as TE = 1/*J* and 2/*J* (*J* denotes the *J*-coupling constant of lactate). However, that technique is not suitable for diagnosing acute stroke because a longer measurement time is required. To shorten the measurement time, we have presented a fast lactate-discriminating echo-planar spectroscopic imaging (EPSI) using the echo-shift technique, which uses a single, optimally chosen TE apart from 1/*J* to shift the echo peak of lactate away from that of lipid [1]. We have shown the usefulness of this fast lactate-discriminating EPSI in analyzing acute ischemic damage through time at 4.7 T using rat models [2]. Although 7-T MRI is more effective in such studies because of its higher signal-to-noise ratio and higher chemical shift resolution, using the echo-shift technique at 7 T has not been clear because the optimum TE depends on a static magnetic field strength and inhomogeneity.

In this paper, we present a fast lactate-discriminating EPSI using the echo-shift technique at 7 T. The TE is optimized at 7 T to satisfy both sufficiently suppressing the lipid signal intensity and lowering the lactate signal distortion caused by the static magnetic field inhomogeneity. Acquisition of discriminated lactate images is demonstrated by applying the presented lactate-discriminating EPSI to a phantom and to a post-mortem rat brain.

Methods

The echo-shift technique for lactate discrimination from lipid consists of (1) setting TE apart from 1/*J*, and (2) calculating the signal intensity at 1/*J* of a time-domain pseudo-signal, which is generated by selecting the spectrum in the lactate chemical shift region and Fourier transforming the selected spectrum [1]. The technique can discriminate lactate because the lactate pseudo-signal maximum is at about 1/*J*, and the lipid pseudo-signal is suppressed at 1/*J* if TE is sufficiently separated from 1/*J* (Fig. 1). The width of the lipid pseudo-signal depends on the static magnetic field strength, and thus, the optimum TE also depends on it. A computer simulation was performed to calculate the pseudo signals of lactate and lipid for various TE values to determine the optimum TE.

We developed a fast lactate-discriminating EPSI using the calculated optimum TE at 7 T. We tested that on a 7-T MRI for small animal study using a phantom and post-mortem rat brain. The phantom consists of a two-layered bottle, of which the inner layer is filled with a 100-mM lactate solution and the outer layer is filled with a 100-mM N-acetylaspartate solution, and cotton with baby oil surrounding the bottle. The lactate-discriminating EPSI was used with a TR of 2000 ms and a TE of 165 ms, which is calculated as optimum by the simulation described above. A 128-cycle sinusoidal oscillating readout gradient was used with a cycle time of 537.6 μs and an amplitude of 68.6 mT/m, and the signal was sampled 96 times per cycle. These parameters were set at a field of view of 64 mm (32 points) in the readout direction and 32 mm (16 points) in the phase-encoding direction, and a spectral bandwidth of 6.2 ppm (128 points). For an accumulation of 8, the total measurement time was 4.2 minutes. The lactate-discriminated image was obtained by performing (2) described above.

Results and Discussion

As shown in Fig. 2, the optimum TE at 7 T is about 165 ms, which satisfies both suppressing the lipid signal to less than 0.1 and maintaining a high lactate signal, while the optimum TE at 4.7 T was about 180 ms. Lactate distributions of the phantom and a rat brain obtained by (a) only selecting the corresponding chemical shift region and by (b) using the presented echo-shift technique with a TE of 165 ms are shown in Figs. 3 and 4, respectively. Clearly, the lipid signal that is shown to come from outside of the bottle or brain is suppressed efficiently by using the presented technique. These data demonstrate that this technique is useful for acquiring an accurate lactate image in a short time period at 7 T. Although the calculated optimum TE is slightly long, this technique is useful for measuring lactate and other major metabolites in a short time period.

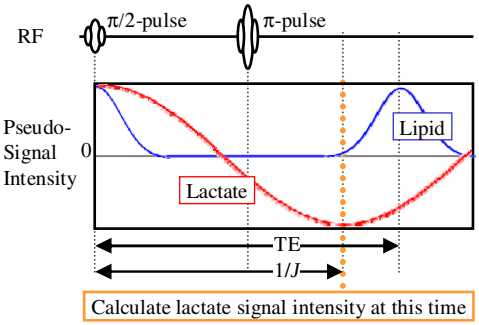


Fig. 1. Echo-shift technique for discriminating lactate signal from lipid signal.

Conclusion

We developed a fast lactate-discriminating EPSI suitable for 7-T MRI. The results suggest this technique can accurately measure lactate distribution in a short time. The technique will be useful both for basic research such as analyzing acute ischemic damage through time, and for clinical use such as more accurate diagnosis of acute cerebral ischemia in a short time period.

References

[1] Bito Y, et al., Magn Reson Med 2001;45:568. [2] Takegami T, et al., NMR Biomed 2001;14:5.

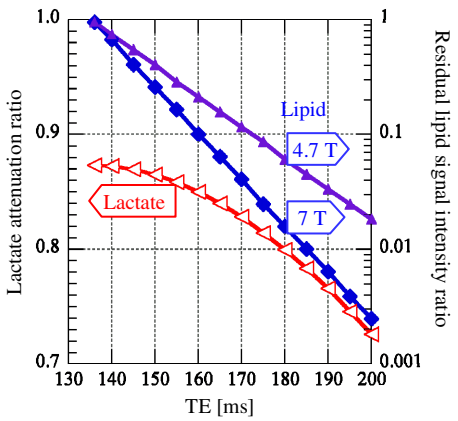
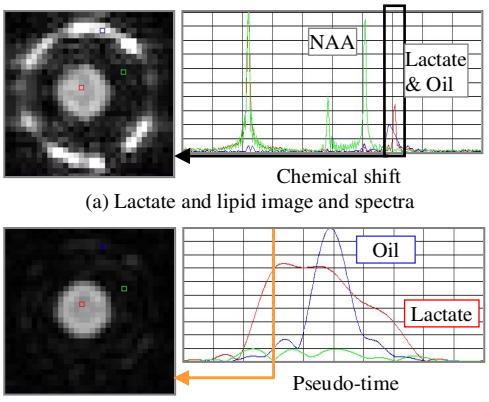


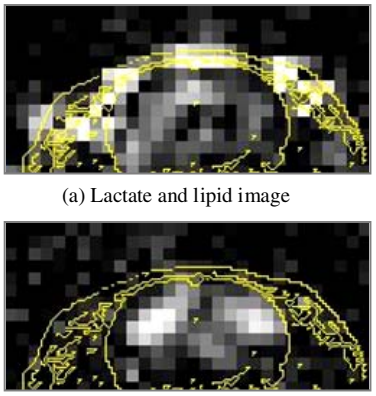
Fig. 2. Lactate attenuation and lipid suppression ratios to those values at TE = 0 vs. TE.



(a) Lactate and lipid image and spectra

(b) Lactate-discriminated image and pseudo-signals

Fig. 3. Lactate-discriminating EPSI of phantom.



(a) Lactate and lipid image

(b) Lactate discriminated image

Fig. 4. Lactate-discriminating EPSI of rat brain.