J-refocused ^{1}H PRESS combined with DEPT for localized saturated fatty acids detection by *in vivo* ^{13}C MRS

Xing Chen[1], Peter Boesiger[1], and Anke Henning[1]
[1]*Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Zurich, Switzerland*

Introduction

Localized natural abundance ^{13}C magnetic resonance spectroscopy (MRS) provides an investigative tool for studying metabolism and energy storage mechanisms *in vivo* [1]. The investigation of lipid composition of adipose and muscle tissue in relation to short- and long-term dietary intake has recently received increased attention [2]. Polarization transfer methods such as Distortionless enhanced polarization transfer (DEPT) [3] can be used to enhance sensitivity in ^{13}C MRS by transferring polarization from highly polarized ^{1}H nuclei to less sensitive ^{13}C spin systems. The combination of DEPT with proton localized PRESS avoids the large chemical shift displacement that occurs for direct ^{13}C localization and enables tissue specific investigation of lipid composition. However, the concurrent strong homonuclear proton scalar coupling in many metabolites like methylene and methyl groups in fatty acids or C3 and C4 in glutamate, modifies the proton spin coherence distribution during proton-PRESS localization, and therefore leads to a substantial reduction in the ^{13}C signal enhancement. The resulting DEPT enhancement is a metabolite specific nonmonotonic function of the PRESS echo times [4]. **In this work**, J-refocused PRESS localized DEPT is introduced to suppress this effect and enable simultaneous and tissue specific DEPT enhancement of multiple fatty acid resonances.

Materials and Methods

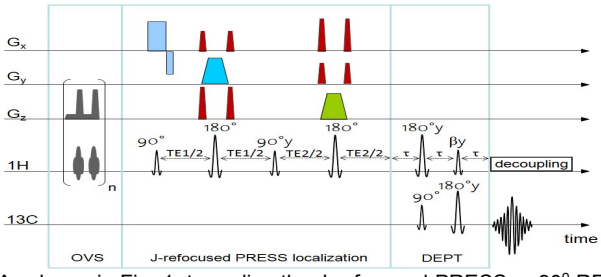

Figure 1 *J-refocused ^{1}H PRESS DEPT sequence.*

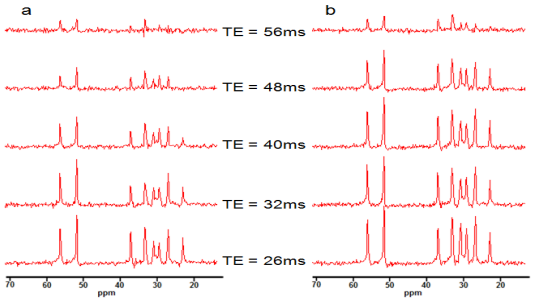

Figure 2 *Glutamate spectra versus TE times: (a) PRESS localized DEPT and (b) J-Refocused PRESS localized DEPT.*

As shown in Fig. 1, to realize the J-refocused PRESS, a 90° RF pulse was inserted in the middle of the double echo PRESS localization part, which reverses the direction of J-coupling evolution at this point [5]. Complete refocusing of scalar coupling terms will be established after the second half of the double-echo sequence while the chemical shifts are refocused by each echo pulse. While J-refocused ^{1}H PRESS substitutes the first 90° pulse of a conventional DEPT experiment, the residual part of the DEPT sequence remains unchanged and was implemented subsequently. The effectiveness of the suppression of J-modulation was investigated by comparing glutamate spectra obtained by using PRESS localized DEPT and J-refocused PRESS localized DEPT at different TE times on a 3T clinical MRI system. Saturated fatty acid components were acquired from a voxel in calf bone marrow on a healthy subject. Broadband proton decoupling was applied for the in vivo experiments.

Results and Discussion

As shown in Fig. 2a, strong J-coupling effects of glutamate distort the phases of C_3 and C_4 resonances and cause rapid loss of signal enhancement as TE increases. In Fig. 2b, the suppression of J modulation is clearly demonstrated by the recovery of in-phase terms and the signal enhancements at various TE times. Fig. 3 plots the normalized ^{13}C intensities versus TE times, with and without J-refocusing. An effective suppression of J modulation by the J-refocusing pulse is achieved when TE is less than 1/4J (J covering from 4Hz to 15Hz) as predicted by product operator calculations. The spectra from the PRESS localized bone marrow area are shown in Fig. 4: (a) ^{13}C PRESS localization with decoupling; (b) ^{13}C PRESS localization with NOE enhancement and decoupling; (c) J-refocused ^{1}H PRESS DEPT localization with decoupling. Enhancement factors for different fat components are measured for NOE and DEPT respectively. With the proposed sequence, a higher signal enhancement could be achieved for all saturated fatty acid resonances where the enhancement factors depend on the time parameters corresponding to the ^{1}H-^{13}C coupling constants from 125 Hz to 145 Hz.

In conclusion, the proposed sequence J-refocused ^{1}H PRESS localized DEPT was implemented for natural abundance 13C MRS. The phantom and in vivo experiments show its feasibility to suppress the homonuclear J-modulation and assess fatty acids and other metabolites of interest in specific positions.

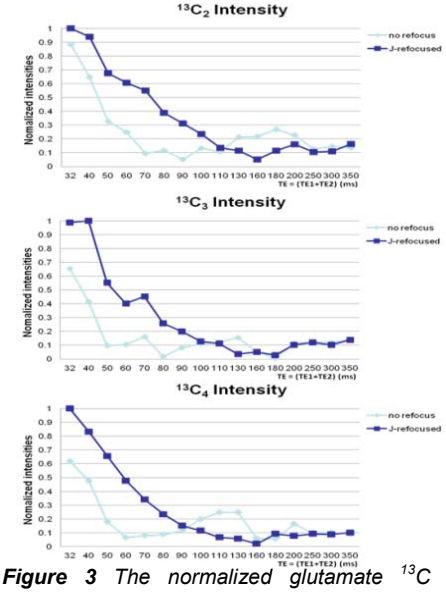

Figure 3 *The normalized glutamate ^{13}C intensities as a function of the PRESS echo times with TE1=TE2 for PRESS localized DEPT (light plot) and J-refocused PRESS localized DEPT (dark plot), respectively.*

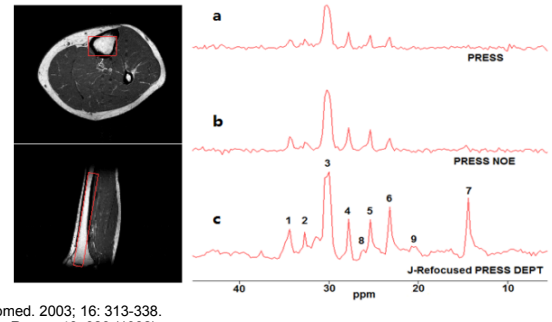

Figure 4 *Saturated fatty acids detection by ^{13}C PRESS (a), ^{13}C PRESS with NOE enhancement (b) and J-refocused ^{1}H PRESS localized DEPT (c) from a 22*30*236mm^3 voxel in the bone marrow (left).*

Peak	Fat component	NOE factor	DEPT factor
(1)	COO-**C**H$_2$-CH$_2$-R	1.435	3.671
(2)	-CH-**C**H$_2$-CH$_3$ (ω3)	0.980	3.686
(3)	(**C**H$_2$)$_n$ envelope	1.308	5.328
(4)	=CH-**C**H$_2$- (allylic *α=cis*)	1.927	3.298
(5)	COO-CH$_2$-**C**H$_2$-	1.794	4.204
(6)	-CH$_2$-**C**H$_2$-CH$_3$	1.397	4.379
(7)	-CH$_2$-**C**H$_3$ (CH$_3$)	-	-
(8)	=CH-**C**H$_2$-CH= (ω3+ω6)	-	-
(9)	=CH-**C**H$_2$-CH$_3$ (ω3, Linolenic)	-	-

Table 1 *Enhancement factors with NOE and J-refocused PRESS localized DEPT respectively for different fat components.*

[1] Rolf Gruetter et al, NMR Biomed. 2003; 16: 313-338.
[2] Jong-Hee Hwang et al, NMR Biomed. 2003; 16: 160-167.
[3] D. M. Doddrell etal, J. Magn. Reson. 48, 323 (1982).
[4] Atiyah Yahya et al, MRM 54:1340-1350 (2005).
[5] Heung K. Lee et al, MRM 34:253-259 (1995).