Prostate Spectroscopy at 3 Tesla Using Two-Dimensional S-PRESS

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Introduction

Magnetic resonance spectroscopy has been established as a useful method for the detection of metabolic changes associated with prostate cancer. Especially the citrate-to-choline concentration ratio is decreased in cancerous prostatic tissue. Therefore, these two metabolites are of prime interest in prostate spectroscopy. However, the strongly coupled citrate resonance experiences a complicated coupling evolution and a signal intensity modulation with echo time. Two-dimensional (2D) *J*-resolved spectroscopy (*J*PRESS) is capable of resolving the coupling information and has thus gained popularity for prostate examinations [1]. Another approach for the detection of strongly coupled spin systems is the difference editing technique S-PRESS [2]. In the present work, a novel 2D technique for the detection of strongly coupled metabolites (2D S-PRESS) is introduced and optimised for prostate spectroscopy at 3 T, yielding the entire spectral information in one single measurement.

Materials and Methods

*J*PRESS and 2D S-PRESS experiments, based on the PRESS sequence $90°_x$ - [$TE_1/2$] - $180°_x$ - [$TE_1/2+TE_2/2$] - $180°_x$ - [$TE_2/2$] – Acq, were performed on a 3T Philips Intera whole body system *in vitro* as well as *in vivo*. In the 2D S-PRESS sequence, the total echo time ($TE = TE_1 + TE_2$) is held constant, while the partial echo times TE_1 and TE_2 are varied simultaneously for encoding TE_1 in the indirect dimension. A *J*PRESS and a 2D S-PRESS spectrum were acquired from a phantom solution containing 15 mM choline (uncoupled), 30 mM lactate (weakly coupled) and 50 mM citrate (strongly coupled). Furthermore, a 2D S-PRESS spectrum was acquired from the prostate of a healthy subject with TE = 282 ms, using a two-element surface coil. From the citrate peak positions the coupling constant *J* and the chemical shift difference δ of the two coupled protons were determined. Using the results from analytical simulations [3], the 2D S-PRESS sequence was optimised for citrate detection by calculating the peak intensity dependence on the echo time.

Results

The phantom spectra illustrate the different behaviour of weakly and strongly coupled spin systems under a *J*PRESS (Fig. 1a) and a 2D S-PRESS (Fig. 1b) sequence. The lactate resonance (weakly coupled) only shows a splitting in the indirect dimension (f_1) for *J*PRESS, but not for 2D S-PRESS. Citrate (strongly coupled) gives rise to a relatively complicated peak pattern in f_1 for *J*PRESS, while in the 2D S-PRESS spectrum there are two characteristic "strong coupling" doublets at $f_1 = \pm\Lambda/2$ (with $\Lambda = (\delta^2 + J^2)^{1/2}$) besides a quartet at $f_1 = 0$. Fig. 2 shows a 2D S-PRESS prostate spectrum with prominent peaks from choline, creatine and citrate (a) as well as a cross-section at $f_1 = -\Lambda/2$ (b) with only a citrate doublet visible. The spectral parameters under *in-vivo* conditions were determined from the positions of the strong coupling peaks in Fig. 2a: J = 15.6 Hz and δ = 20.1 Hz. The TE-dependent intensity modulation of the strong coupling peaks was calculated with these values (Fig. 3a). The result was verified by an additional *in-vivo* 2D S-PRESS experiment with TE = 235 ms (Fig. 3b), where the strong coupling peaks are expected to vanish according to the intensity graph (Fig. 3a). Their complete extinction demonstrates the accuracy of the determined spectral parameters.

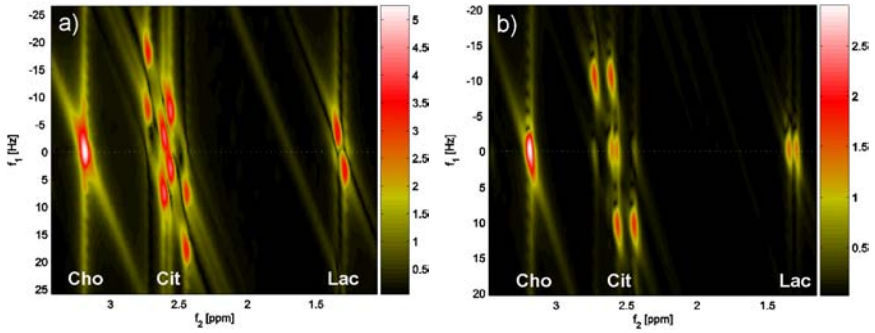

Fig. 1: *J*PRESS (a) and 2D S-PRESS (b) phantom spectra in magnitude mode with the same encoding range in the indirect dimension, showing resonances of choline (Cho), citrate (Cit) and lactate (Lac).

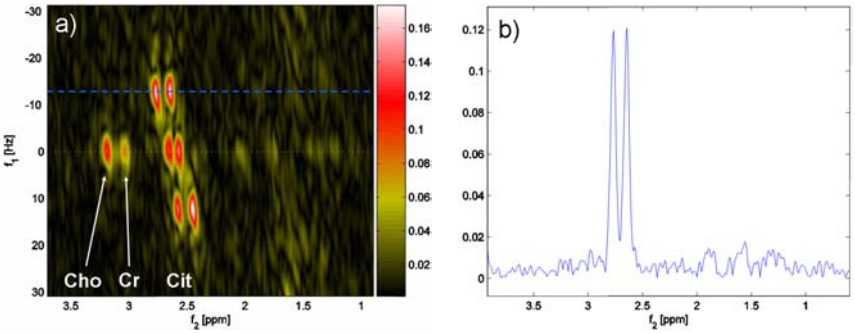

Fig. 2: a) In-vivo 2D S-PRESS magnitude spectrum, acquired with TE = 282 ms, showing resonances of choline (Cho), creatine (Cr) and citrate (Cit). b) Cross-section at $f_1 = -\Lambda/2 = -12.7$ Hz.

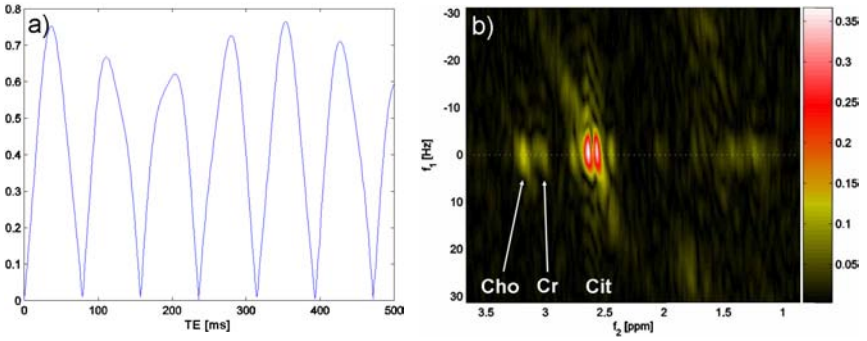

Fig. 3: a) Intensity modulation of the strong coupling peaks with echo time according to analytical calculations neglecting relaxation. b) In-vivo 2D S-PRESS spectrum acquired with TE = 235 ms.

Discussion and Conclusions

The 2D S-PRESS technique enables an improved resolution and characterisation of the citrate signal, allowing for an accurate determination of the spectral parameters J and δ *in vivo*: Therefore, it is superior to the 1D difference editing approach. Since a short TE impairs the spectral resolution in f_1 and a long TE reduces the SNR due to T_2 relaxation, Fig. 3a suggests an optimal echo time of 280 ms for 2D S-PRESS prostate spectroscopy. As only the resonances of strongly coupled spin systems are spread into the indirect dimension, 2D S-PRESS gives rise to more clearly arranged spectra than *J*PRESS and facilitates the distinction of weakly and strongly coupled metabolites. Since J and δ sensitively depend on the concentration of divalent ions in the tissue [4], 2D S-PRESS might enable the detection of prostate cancer on the basis of a change of these spectral parameters due to a largely reduced zinc concentration observed in cancerous tissue.

References:

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