Efficient ^{1}H to ^{31}P polarization transfer on a clinical MR system with a single RF transmit channel

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Introduction

Treatment selection for tumours relies on accurate discrimination between different tumour types. In many diagnostic examinations, MR spectroscopy (MRS) is added to increase the specificity of tumour-type determination or to follow tumour treatment. Choline containing metabolites are one of the most important markers in MRS of tumours. Although ^{1}H MRS can be used to detect the total choline pool in tissue, ^{31}P MRS can be used to even discriminate between phosphocholine (PC) and glycerol phosphocholine (GPC). In addition, ^{31}P MRS can detect phophoryl elthanolamine (PE) and glycerol phosphoethanolamine (GPE). It has been shown that PC, PE, GPC and GPE can indeed be used as early markers for response and predictions to treatment [1,2]. Although specificity can increase with ^{31}P MRS compared to ^{1}H MRS, the sensitivity is lower. Several techniques have been proposed to improve the ^{31}P sensitivity using ^{1}H to ^{31}P polarization transfer [3]. However, due to J couplings between ^{31}P and ^{1}H that have similar magnitudes for homonuclear J couplings in PC, PE, GPE and GPC, the sensitivity enhancement is less than 50% of the potential enhancement of γ_{1H}/γ_{31P} (i.e. 2.4 fold). A method to cancel homonuclear J coupling effects in polarization transfer experiments is to apply frequency selective refocusing pulses during spin evolution. In this study we demonstrate the possibility to implement chemical shift selective refocusing pulses that fit into optimized echo times of an INEPT sequence achieving full ^{1}H to ^{31}P polarization transfer in PC, PE, GPE and GPC. This procedure can be implemented on a clinical 3T broadband MR system with a single transmit RF system.

Methods

When no homonuclear J coupling effects are present, a refocused INEPT method can be used for ^{1}H to ^{31}P polarization transfer with a ^{1}H echo time of 80ms (i.e. 1/2J) followed by a ^{31}P echo time of 40ms (i.e. 1/4J, optimized for PC and PE). Within 80 ms, a non selective ^{1}H refocusing pulse in combination with 2 selective refocusing pulses on the ^{1}H nuclei that have similar J couplings is used. In addition, an ISIS localization scheme is added. Adiabatic (BIR4) ^{31}P pulses are employed and a small echo shift is included to allow polarization transfer on a single RF channel [4] (Figure 1). The ^{1}H chemical shifts of the nuclei that have homonuclear J couplings similar to the heteronuclear J couplings are 3.64 versus 4.28ppm (PC), 3.66 versus 4.31ppm (GPC) and 3.22 versus 3.98ppm (PE) of which the higher field resonances are coupled to the ^{31}P nucleus [5]. This requires selective refocusing pulses with a slope of maximum 3.98-3.66 = 0.32ppm such that the pulse affects the higher field resonances without affecting the lower field resonances. A Shinar le Roux algorithm is used to design such an RF pulse with sufficient chemical shift selectivity at 3T using 32ms as a time constraint and assuming homogenous ^{1}H excitation. A sensitivity optimized coil setup is used for ^{31}P detection in human brain at 3T consisting of two slightly overlapping surface coils in quadrature operation shifted into a quadrature ^{1}H birdcage coil [6]. The coil is interfaced to a broadband clinical 3T MR system (TRIO TIM, Siemens, Erlangen) without a second RF channel. The ISIS localised refocused INEPT method with chemical shift selective refocusing pulses is applied on a 23 years old healthy volunteer. The results are compared with an ISIS localised direct ^{31}P pulse-acquire method using adiabatic excitation. In both methods, the volume of excitation was $(5cm)^3$, TR was 10s (to minimize T1 effects) , number of acquisitions was 32 and ^{1}H decoupling was applied during ^{31}P detection (400ms WALTZ16).

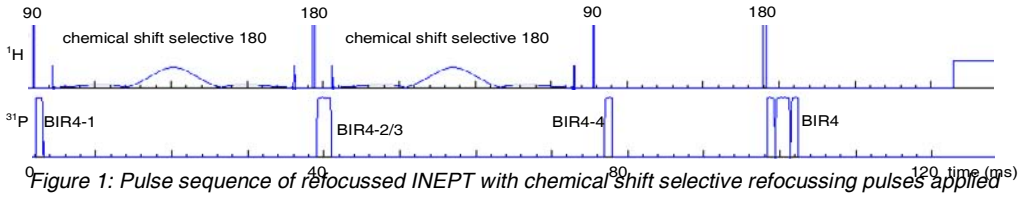

Figure 1: Pulse sequence of refocussed INEPT with chemical shift selective refocussing pulses applied on a single transmit channel (pulses are applied sequentially with a frequency switch delay of 100us).

Results and discussion

The simulated frequency profile of the chemical shift selective refocusing pulse is shown in figure 2. As can be seen the selectivity of the pulse is sufficient for use at 3T. A comparison between direct ^{31}P acquisition and acquisition by polarization transfer using a single transmit channel shows improved sensitivity (up to 40%) and spectral resolution (figure 3). The latter can be due to the selectivity of the refocusing pulses or T2 relaxation.

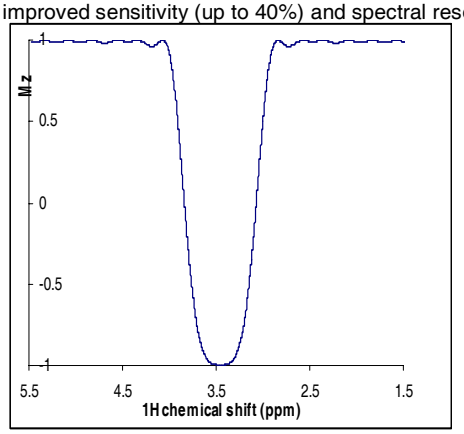

Figure 2: Frequency profile of the chemical shift selective refocusing pulses

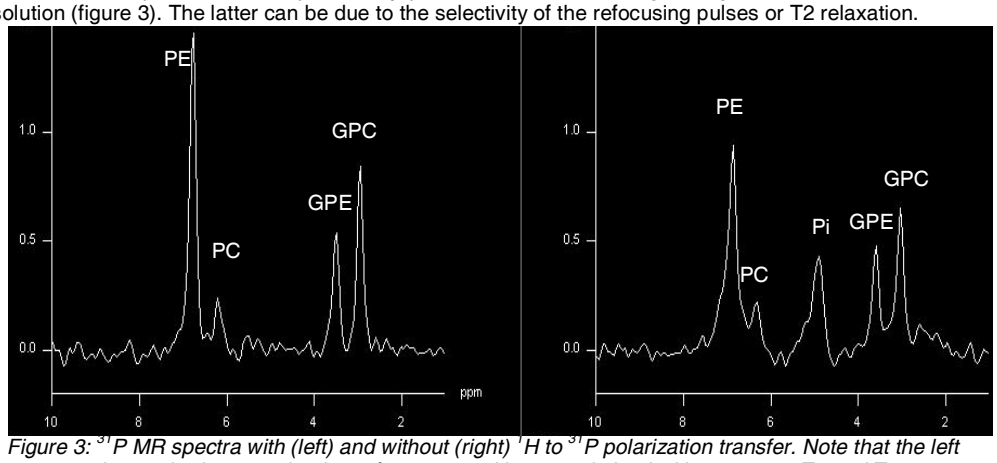

Figure 3: ^{31}P MR spectra with (left) and without (right) ^{1}H to ^{31}P polarization transfer. Note that the left spectrum is acquired at an echo time of 140ms, and is not optimized with respect to T1 and T2.

Conclusion

These preliminary results indicate that chemical shift selective pulses can be used to enable ^{1}H to ^{31}P polarization transfer effectively for PC, PE, GPE and GPC. Additionally we have shown that ^{1}H to ^{31}P polarization transfer is feasible on a broadband clinical MR system with only a single RF transmit channel. Knowledge of T1 and T2 times of PC and GPC for ^{1}H and ^{31}P could further improve the sensitivity of the proposed method by adjusting the timings from the sequence accordingly.

References[1] Negendank. NMR Biomed 1992;5:303; [2] Arias-Mendosa et al. NMR Biomed. 2006;19(4):504; [3] Mancini et al. Magn Reson Med 2005;54:1065; [4] Klomp et al. ISMRM2006;589; [5] Gavindaraju et al. NMR Biomed 2000;13:129; [6] Klomp et al. Magn Reson Med 2006;55:271.