Full 1H to 31P polarization transfer on 7 Tesla.

W. van der Kemp[1], V. Boer[1], P. Luijten[1], and D. Klomp[1]
[1]Department of Radiology, University Medical Center, Utrecht, Netherlands

Introduction
The monoesters phosphocholine (PC), phosphoethanolamine (PE) and the diesters glycerophosphocholine (GPC) and glycerolphospho-ethanolamine (GPE), involved in phospholipid metabolism, have shown clinical potential as a biomarker for oncological and degenerative diseases. Direct ^{31}P measurement however is hampered by an intrinsic low sensitivity. ^{1}H to ^{31}P polarization transfer methods (e.g. DEPT and RINEPT) have been proposed to achieve a potential signal enhancement of 2.4 ($\gamma^{1}H/\gamma^{31}P$). Achieving the full transfer for these compounds is impeded by scalar coupling between the ^{1}H spins J_{HH} (fig 1). This can be overcome by selective refocusing (sRINEPT) of the hydrogen nuclei [1]. However, since the resonance frequency of the hydrogen nuclei is different for the choline and ethanolamine compounds, only a small overlap exists (13 Hz @ 1.5T) where all four compounds can be refocused for full signal enhancement. At 1.5T, or even at 3T, it is therefore difficult to design selective pulses for this purpose. Additionally, B_0 inhomogeneity or frequency miscalibration will cause severe signal loss on some or all of the compounds. At higher B_0 field strength not only the intrinsic signal to noise ratio increases, but the increase in chemical shift dispersion allows for a transfer sequence which is more robust to frequency variations which are present in the human body. In this work the sRINEPT sequence is implemented for 7 Tesla where the refocusing window is as much as 60 Hz. Phantom results are shown where full signal enhancement can be reached over a relatively large bandwidth, thereby greatly increasing the robustness of the sequence for clinical practice in the detection of the compounds (G)PC and (G)PE in the human body at high sensitivity.

Methods:
Both quantum mechanical simulations and phantom measurement were performed with a whole body 7 Tesla MR system (Philips, Cleveland, USA) using a home-built dual-tuned coil to asses the sensitivity of the sequence to frequency variations. An sRINEPT sequence was implemented with one selective refocusing pulse on the ^{1}H channel during the first evolution time (fig 2). The transition band of this selective refocusing pulse was 30 Hz and set between 3.66 and 3.98 ppm to invert the hydrogen nuclei at C1 while not perturbing those at C2, thereby refocusing the scalar coupling J_{HH} for all (G)PE and (G)PC compounds.
Additionally, since in general pulse angle calibration is only possible for the ^{1}H channel and also for compensation of spatial varying B_1^+ field at 7T, a BIR-4 adiabatic pulse was implemented on the ^{31}P channel to make the sequence insensitive to B_1^+ variations over the region of interest.

Results:
Quantum mechanical simulations show that there exists a 0.2 ppm band width (fig 3, left) where both PC and PE compounds have full transfer efficiency with the sRINEPT sequence corresponding to a 60 Hz band at 7T. Measurement on a PC solution phantom (fig 3, right) show a comparable efficiency as a function of frequency offset.
An experiment comparing the transfer efficiency with the adiabatic BIR-4 pulse compared to conventional block pulses (fig 5) shows that signal loss due to flip angle miscalibration and spatially varying B_1^+ can be regained since the BIR-4 pulse is insensitive to B_1^+ variations in the region of interest.

Conclusion and discussion:
Full polarization transfer of ^{1}H to ^{31}P spins has been demonstrated for phosphomonoesters using a sRINEPT sequence. At 7T, we demonstrated that such sequence can be applied with very selective refocusing pulses resulting in maximum transfer within a 60Hz offset. In addition, the sequence can be combined with adiabatic RF pulses that allow non uniform B_1 fields of the ^{31}P setup without compromised SNR.

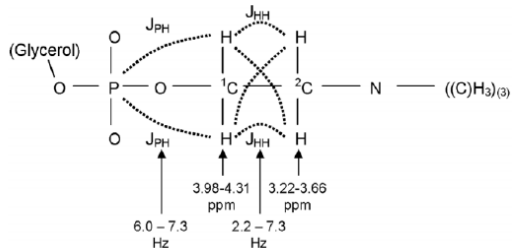


Fig 1. Chemical structure, proton chemical shifts and coupling constants of (G)PC and G(PE).

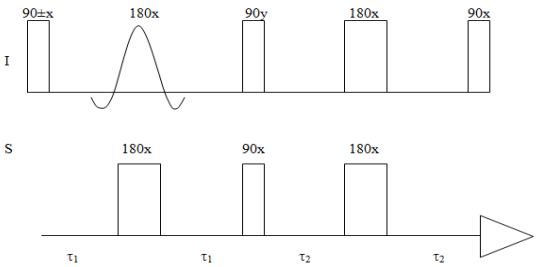
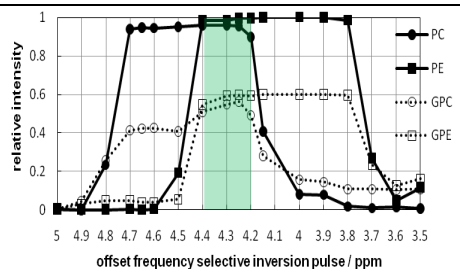


Fig 2. sRINEPT sequence with one selective refocusing pulse in the first interval (τ_1= 36 ms, τ_2 = 17 ms).



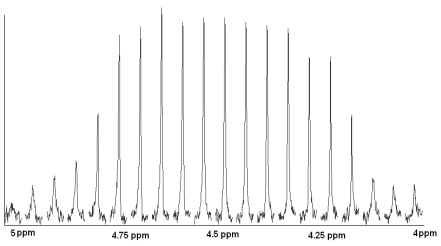


Figure 3. Simulated (left) of relative intensities of (G)PC and (G)PE as a function of the selective inversion pulse offset frequency on the protons at C1-position. Phantom measurements (rigth) on a choline phantom show a similar frequency response.

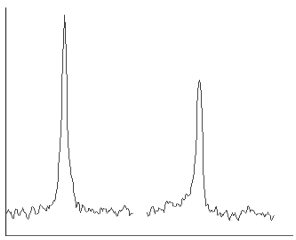


Figure 4. ^{31}P signal intensity as measured on a PC phantom shows how signal loss due to B_1 variation in the phantom can be compensated with the adiabatic BIR-4 pulse on ^{31}P (left) compared to block pulses even after iterative flip angle calibration for ^{31}P (right).

[1] D.W.J. Klomp, J.P.Wijnen, T.W.J. Scheenen, A. Heerschap, MRM 2008; 60(6) 1298.