

Chemical Shift Artifact Free Volume Selection for 31P MRS

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Very Selective Suppression (VSS) pulses with an excitation bandwidth of 11kHz were incorporated in a 31P MRS spin-echo sequence to minimize chemical shift artifacts. The VSS pulses' suppression performance of the MR signal within the suppression band and their insensitivity to chemical shift was validated in phantom experiments. In vivo spectra of excellent quality were obtained from three volunteers. Localized 31P with VSS volume selection is feasible and provides spectra with minimal chemical shift artifacts. Minimizing chemical shift artifacts are of importance for studying focal diseases such as brain tumors with proton decoupled 31P MRS (31P[1H]).

Introduction: 31P[1H] MRS in vivo is compromised by low signal intensity, low spatial resolution, voxel bleeding of low resolution CSI, and significant chemical shift artifacts due to the large dispersion of the 31P spectrum. Chemical shift artifacts (CSA) arise from different frequencies associated with resonances of different chemical structures and cause the excited volume for the different chemical structures to be offset from one another. The bandwidth of an excitation pulse and the structures' frequency difference determine the size of this offset. The feasibility of efficient chemical shift independent spatial suppression using VSS pulses has been demonstrated earlier for 1H MRS (1). The goal of this study was to demonstrate that 31P MRS with VSS pulses results in a significant improvement of the chemical shift problem in 31P MRS.

Methods and Materials: All experiments were carried out on a clinical 1.5T GE scanner, equipped with a stand-alone decoupler (GEMS, Fremont, CA), using a double tuned head coil (AIRI, Cleveland, OH). VSS pulses with a bandwidth of 11kHz were added to a spin-echo sequence with a self-refocusing RF pulse with TE = 2.5ms. The VSS pulses' suppression efficiency of unwanted signal was tested by acquiring 2D CSI spectra with 24x24 phase encoding steps from the standard GE head phantom

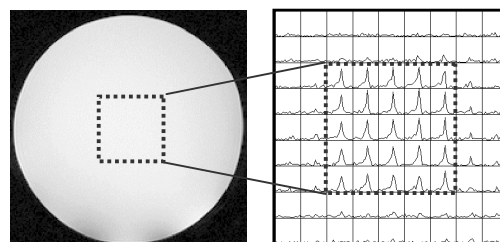


Figure 1A 2D CSI from GE Head Phantom.

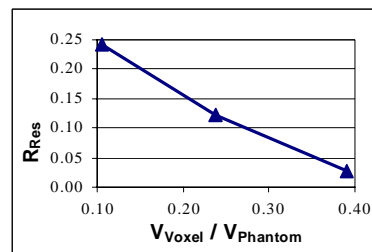


Figure 1B R_{Res} as a function of voxel volume (V_{Voxel}) relative to the total excited volume (V_{Phantom}).

containing 50 mM inorganic phosphate (PO_4). VSS bands were set to suppress all signal outside a voxel graphically prescribed on a localizer MRI. Suppression efficiency was determined by calculating the residual signal percentage, $R_{\text{Res}} = (S_{\text{Total}} - S_{\text{Voxel}}) / S_{\text{Total}}$, where S_{Voxel} is the sum of all CSI voxels contained in the voxel and S_{Total} is the sum of all CSI voxels in the plane.

CSA independent volume selection was demonstrated using a two-compartment phantom with highly concentrated PO_4 in the large compartment and pyrophosphate (P_2O_7) in the small compartment. A slice was excited (Slice_{Rx}) immediately adjacent to the P_2O_7 compartment using the 1.6kHz self-refocusing RF pulse. This experiment was repeated with additional suppression of signal outside the region of interest using 11kHz VSS pulses (Figure 2). Spectra were processed using the Sage/IDL software (GEMS, Fremont, CA).

Results: The VSS pulses produced excellent suppression of the PO_4 peak outside the prescribed voxel (Figure 1A). Residual signal, mainly from voxels in the transition band surrounding the region of interest, was less than 5% of S_{Total} for voxels that were more than 35% of the total signal volume in the acquisition (Figure 1B). The chemical shift artifact was completely eliminated by saturating magnetization outside the region of interest with VSS pulses, leaving the PO_4 signal amplitude unaffected (Figure 2). In vivo 31P[1H] spectra of high quality spectra were obtained (Figure 3).

Discussion: Using typical excitation pulses of 1.6kHz the chemical shift displacement/artifact of the phosphorylethanolamine peak at 6.8 ppm and β -ATP at -16.7 ppm is 35% of the excited volume in each spatial direction at 1.5 Tesla. One strategy to avoid chemical shift artifacts is to non-selectively excite the whole volume followed by 3D spatial phase encoding. However, this method is too time-consuming in clinical practice. Furthermore, large contributions from membrane lipids to the underlying baseline and the necessity of 1st order phasing comprise the quantitation of metabolites. We have evaluated a slice selective spin-echo sequence that can be combined with 2D in-plane phase encoding. Partial saturation of magnetization outside the volume of interest with high bandwidth VSS pulses prior to excitation effectively eliminated the CSA (Figure 2). Minimizing the CSA is of importance for studying focal diseases such as brain tumors with 31P[1H] MRS.

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Reference: 1. Tran T-KC, Vigneron DB, Sailasuta N, Tropp J, LeRoux P, Kurhanewicz J, Nelson S, Hurd R. Very selective suppression pulses for clinical MRSI studies of brain and prostate cancer. Magn. Reson. Med. 2000;43:23-33

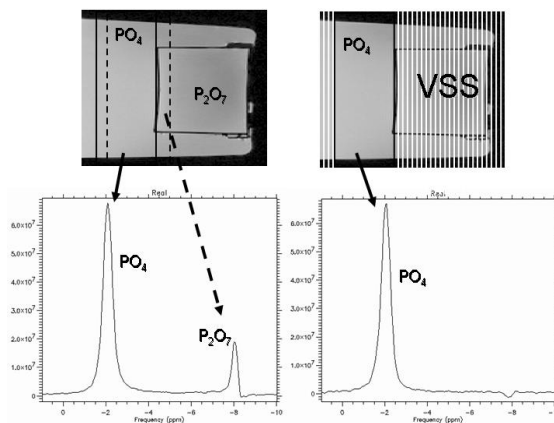


Figure 2 Due to the CSA, the slice location of PO_4 (solid line) differed from the slice location of P_2O_7 (dashed line) causing bleeding of P_2O_7 signal into the spectrum (left). The CSA was completely eliminated when VSS Pulses were applied (right).

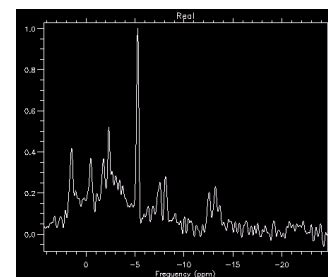


Figure 3 In-vivo $^{31}\text{P}[^1\text{H}]$ using a stand-alone decoupler.