# Lactate Detection Using Double Quantum Coherence Filtering with Spectral-Spatial Refocusing RF Pulses in a PRESS Sequence

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**Introduction:**

Double-quantum coherence filtering (DQF) with PRESS localization has been used for spectral editing in MRS [1]. Previous studies have shown that DQF with PRESS can selectively detect signals from metabolites such as lactate. However, these techniques face several challenges [2]. For example, chemical shifts among different metabolites can result in spatial mismatch of the slice-selective 180° RF pulses. The mismatch increases with field strength and leads to substantial reduction in signal-to-noise ratio (SNR). In this work, we have employed spatially-spectrally (SPSP) selective refocusing pulses to replace non-spectrally selective pulses used in previous DQF-PRESS sequences [1]. Results from phantoms and human subjects have shown that the new method can provide accurate spatial localization even in the presence of large chemical shifts, leading to more effective lactate editing.

**Methods:**

The two SPSP refocusing RF pulses in the DQF-PRESS sequence (Fig. 1) were designed according to the guidelines given in [3,4]. Each refocusing pulse consisted of 31 sub-pulses with a pulse width of 0.258 ms and a bandwidth of 4.6 kHz. These sub-pulses were designed using a Shinnar-Le Roux (SLR) algorithm with a linear phase and optimized using a variable-rate selective excitation (VERSE) technique [5] to improve the time efficiency. All sub-pulses were placed under an envelope of a spectrally-selective SLR RF pulse (pulse width = 8 ms and bandwidth = 760 Hz) to form an SPSP refocusing pulse. The SPSP refocusing pulses were incorporated into a DQF-PRESS sequence, resulting in a DQF-PRESS-SPSP sequence (Fig. 1). To evaluate the frequency response of the SPSP pulse, a spin-echo pulse sequence with the SPSP refocusing pulse was modified by adding a constant gradient to the readout direction to mimic the chemical shift dimension. Phase-encoding was applied along the slice-selection direction to visualize the spatial response of the SPSP pulse. To illustrate the robustness against the spatial mismatch due to chemical shifts, another spin echo pulse sequence with the SPSP refocusing pulse was modified by applying a phase-encoding gradient along the slice-selection direction, and applied to a cylindrical phantom consisting of two coaxial compartments of water/lactate (inner) and lipids (outer) (Fig. 3, left). After the two spin-echo experiments, a spherical lactate phantom (60 mM) was used to compare the performance of the DQF-PRESS-SPSP sequence with a conventional DQF-PRESS sequence [1]. Furthermore, *in vivo* experiments were conducted on the left calf muscle of a human volunteer to detect lactate before and after intensive exercise. All experiments were conducted on a 3T GE Signa HDx scanner using quadrature volume coils. The key data acquisition parameters were TR /TE =1500/142ms, $\tau/t_1/\tau_1/\tau_2$ = 71/7.9/27.6/43.4ms, NEX = 2-8 for phantoms and 256 for human studies.

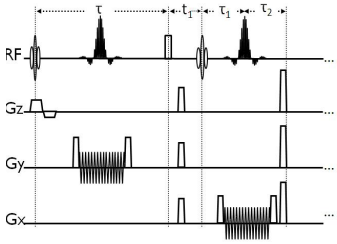


**Fig. 1** A diagram of the DQF-PRESS-SPSP sequence.

**Results:**

Figure 2a displays the spatial (vertical) and spectral (horizontal) response of the SPSP refocusing pulse, as revealed by the first spin echo experiment. Figures 2b and 2c show the slice profile from the second spin-echo experiment using a non-SPSP refocusing pulse and the SPSP refocusing pulse, respectively. The spatial displacement induced by chemical shift between water (inner) and lipids (outer) was clearly visible in Fig. 2b (arrow), but effectively eliminated in Fig. 2c. Figure 3 shows the performance of DQF-PRESS-SPSP for lactate detection in the presence of overlapping liquid signals. The three PRESS voxels contained (a) predominantly lactate in water, (b) partial lipids and partial lactate, and (c) all lipids. The corresponding spectra illustrated decreased lactate peaks, as expected. Figure 4 shows the spectra from a single voxel selected from the lactate-containing spherical phantom (no lipids) using (a) conventional PRESS, (b) DQF-PRESS-SPSP, and (c) DQF-PRESS without SPSP, respectively. The doublets of lactate were resolved in all three cases. The SNR in (b) was ~40% of that in (a), but approximately two times higher than that in (c) due to the elimination of spatial mismatching. Results from the human volunteer are shown in Fig. 5 where the lactate signal was disguised by lipids in conventional PRESS (a), but successfully recovered by DQF-PRESS-SPSP (b) after intensive exercise. The presence of lactate signal was further confirmed by comparing the spectra from the same subject before (c) and after (b) exercise.

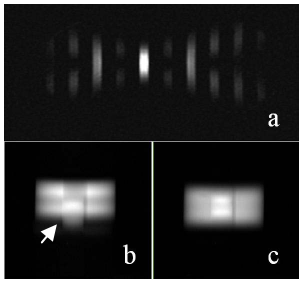


**Fig. 2**

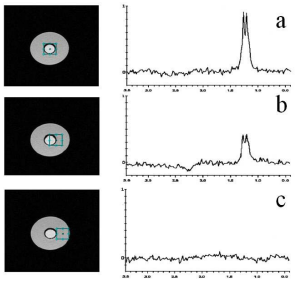


**Fig. 3**

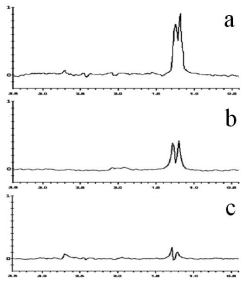


**Fig. 4**

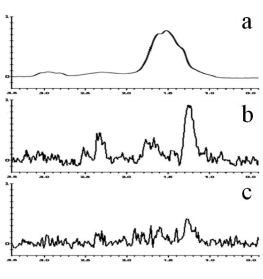


**Fig. 5**

**Discussion and Conclusions:**

Our results have shown that SPSP refocusing RF pulses can improve the performance of DQF for localized lactate editing. This approach eliminates the spatial mismatch arising from chemical shifts, leading to increased SNR (Fig. 4). When compared to conventional PRESS (Fig. 4a), the SNR reduction (40%) in DQF-PRESS-SPSP was close to the theoretical value (50%). The discrepancy may be caused by the difference in spatial profile. We have also demonstrated the feasibility of applying this technique to human subjects. With further improvements in RF slice profile, the proposed DQF-PRESS-SPSP sequence is expected to find applications for lactate detection in a number of disease processes.

**References:** [1] Laurence J, et al, MRM 36:487-490 (1996). [2] Hao Lei, et al, JMR 150: 17–25 (2001). [3] Meyer CH, et al, MRM 15:287-304 (1990). [4] Pauly JM, et al, MRM 29:776-82 (1993). [5] Conolly S, et al, JMR 78:440-458 (1988).

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