The gland down under: effect of selective RF pulses on citrate lineshapes at 3T

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MR spectroscopy can be used to help diagnose and monitor prostate cancer. Two metabolites are of particular interest: (a) citrate, a marker of healthy prostatic tissue, and (b) choline, a marker for prostate cancer when elevated. Citrate is strongly coupled AB system (J=16.1 Hz, $\Delta\sigma$=0.15 ppm) with four peaks at ~2.61 ppm whose phases and amplitudes are notably sensitive to sequence timing at 3T. The lineshape is also affected by changes in J modulation caused by multiple RF pulses [1] or changes that occur *during* slice-selective or spectrally selective pulses. This effect must be modeled properly to obtain accurate lineshapes for fitting prostate spectra.

As an example, two simulated 3T citrate lineshapes appear in Figure 1 for a PRESS sequence with TE = 136 ms and a first echo time of 26 ms. The spectrum on the left was calculated assuming hard 180° refocusing pulses, whereas 9 ms shaped refocusing pulses (centered at the citrate frequency) were explicitly included in the calculation of the spectrum on the right.

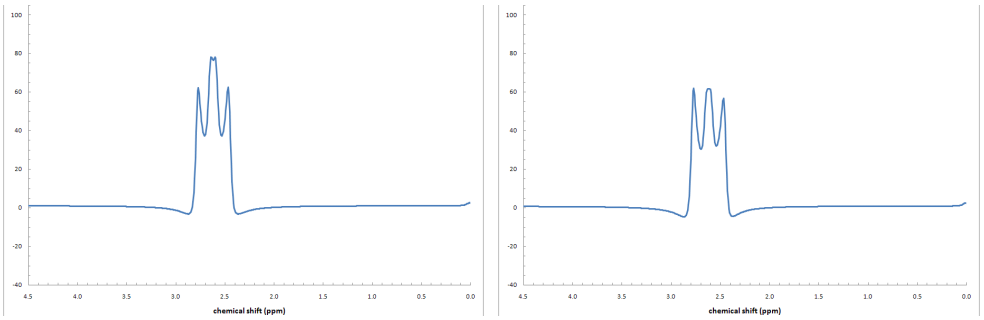
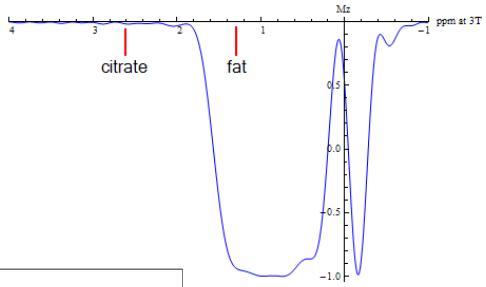


Fig 1. TE 136 PRESS spectrum of citrate at 3T calculated with hard 180° pulses (left) and with 9 ms slice-selective refocusing pulses (right).

Fig 2. BASING pulse inversion profile



A more dramatic *(and surprising)* change to the spectrum occurred when two spectrally selective BASING (= MEGA) pulses were included in the sequence for better fat suppression [2-4]. In particular, two 35 ms asymmetric phase-modulated inversion pulses were first optimized for a relatively narrow 0.6 ppm transition zone between fat and citrate and an insensitivity to B_1 inhomogeneity of ±40%. Along with attendant crusher gradients, these were then added symmetrically around the second slice-selective refocusing pulse. Both in simulations and in single-voxel prostate spectra acquired on a prototype Toshiba 3T scanner, these BASING pulses (when applied with ν_{1max} = 430 Hz) had a noticeable effect on citrate spin evolution and hence the citrate lineshape, even though the citrate resonance was well beyond their inversion profile. (See Figures 2 and 3.)

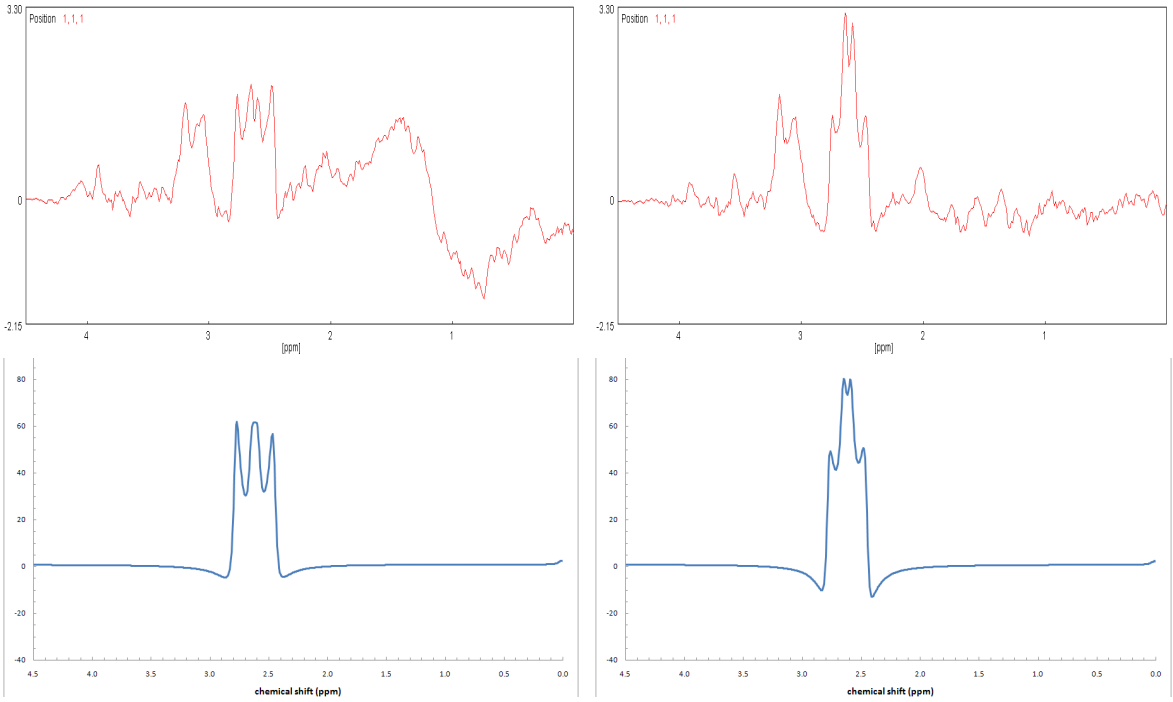


Fig 3. 3T prostate spectra and corresponding citrate peak simulations for a TE 136 PRESS sequence (left) and a TE 136 PRESS + BASING sequence (right). Both experimental spectra also include a combined creatine + spermine + choline peak at 3.0-3.2 ppm. In addition, a broad out-of-phase lipid peak appears in the PRESS spectrum.

By calculating spin evolution during both spatially and spectrally selective pulses, we were able to generate reasonably accurate citrate lineshapes for subsequent fitting. Furthermore, note the improved SNR of the citrate peak in the PRESS + BASING spectrum – indicative of an off-resonance effect on J modulation. Because there is considerable freedom in the design of BASING inversion pulses, we can choose pulse shapes that not only suppress fat robustly, but also sharpen citrate peaks in a manner similar to an MLEV-PRESS sequence [5,6] – two good results from one set of squiggles.

References: (1) Hennig et al, MRM **37**, 816-820, 1997; (2) Mescher et al, J Magn Reson A **123**, 226-229, 1996; (3) Star-Lack et al, MRM **38**, 311-321, 1997; (4) Males et al, MRM **43**, 17-22, 2000; (5) Cunningham et al, MRM **53**, 1033-1039, 2005; (6) Chen et al, Magn Reson Imag **24**, 825-832, 2006.