Single slab-selective 3D CPMG multi-echo sequence with short inter-echo spacing for short-component T2 quantitation

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Introduction: A 3D single slab-selective Carr-Purcell-Meiboom-Gill (CPMG) pulse sequence was developed for the detection of short T2 components, e.g., as applied in the brain for the detection of a component presumably from myelin associated water (MAW). Such applications require both high SNR and short inter-echo spacing. To date, this is achieved using single slice 2D CPMG imaging sequences with non-spatially selective refocusing pulses and multiple signal averages, requiring appx. 25 mins of scan time. Although this scan time can be used more efficiently in conjunction with 3D spatial localization, high quality slab-selective pulses are then necessary that would necessarily elongate the inter echo spacing, thus conflicting with the detection of fast relaxing components. To alleviate this issue a dual echo spacing approach [2,3] was used; the first echo occurs at a longer echo time, necessary to accommodate the slab-selective pulse, while the non-selective refocusing pulses are closely packed to obtain the minimum echo spacing possible. Large volume coverage for accurate generation of T2 maps can then be accomplished in typical scan times.

Methods: The sequence developed (Fig. 1) was based on the conditions set forth in [1]. Specifically, all phase encoding (y & z) was performed prior to the refocusing train. Additionally, dephasing gradients of alternating and reducing magnitude were applied along the slice-encode dimension. A 6 ms Shinnar-Le Roux pulse was designed with a time-bandwidth product of 18 msec-Khz, necessitating that the first echo occur 11.9 ms after the nutation reference. The subsequent echoes, formed by the hard non-selective refocusing pulses, were however spaced only 4.8 ms apart, largely limited by the areas of the dephasing gradients. For comparison with the resulting decay curves, two similar pulse sequences were also used. The first did not employ a selective pulse, requiring that the entire sample volume be imaged at the desired resolution. The inter-echo interval of this sequence was also 4.8 ms for all echoes (i.e., including the first). The second sequence did employ the slab-selective 90 pulse, but did not use the dual echo spacing approach, with all echoes spaced 10.11 ms apart. Two dual-chamber phantoms were concurrently imaged, one containing two Gd doped water solutions, and one containing two MnCl2 solutions. Each sequence was applied with the same target voxel size of 1.56x1.56x6 mm and a TR of 2 s. The fully non-selective sequence required a FOV of 20x20x13.2 cm and a total imaging time of 93 mins, while the two slab-selective sequences were applied over a 20x20x4.8 cm volume, necessitating 34 mins. For each scan 3 volumes were chosen in the same locations for each scan: one in the 10 ms Gd chamber, one in the 30 ms chamber and one overlapping both chambers. These results were used to test the reliability of the decay curves, and of the biexponential fitting for the dual echo-spacing sequence. Additionally, a healthy volunteer was imaged in a 1.5T MR scanner (Signa LX EchoSpeed, GE Medical Systems, Milwaukee, WI) using the slab-selective dual echo-spacing sequence. A 24x24x6.8 cm volume was imaged, in a 25 min scan yielding 2.5x1.88x8 mm voxels.

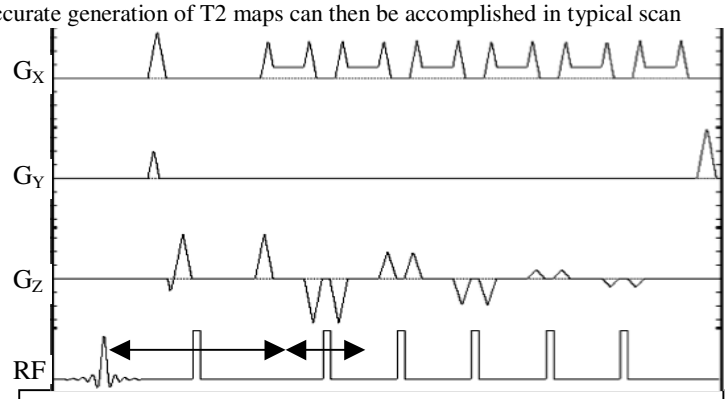

Figure 1. Single-slab 3D CPMG multi-echo sequence. A 6ms 90x excitation is used to select a slab. After formation of the first echo (at 11.76ms, first arrow), subsequent echoes are formed by closely spaced 180y pulses (4.9ms spacing, 2nd arrow).

Results and Discussion: The table on the right summarizes the measured relaxation rates for the 3 scans of the Gd dual-chamber phantom. A bi-exponential analysis of the decay measured by the slab-select 10.11 ms single echo-spacing sequence in the 10 ms Gd ROI compartment showed that a 1.2% (inexistent) 80 ms component was present as well. The dual echo-spacing and the non-selective sequences however respectively only showed a minimal 0.2% and 0.3% 4 s component necessary to account for the baseline. For the singe echo-spacing sequence the mono-exponential fit in that ROI was departed from at the 5th echo, versus at the 8th for the dual echo-spacing sequence. Additionally, the presence of that component in the overlapping ROI compartment was also underestimated by a factor of 10% in the single echo-spacing sequence. Note that (only) the slice centers for the non-selective scan were slightly offset, leading to slightly different concentrations of each compartment in the overlapping ROI measurements. The individual compartment ROIs were chosen well within the compartments to avoid other signal contamination. Decay curves from white matter regions of the human brain (Fig. 2) were also well-suited to biexponential analyses which revealed a short T2 component signal (T2 around 10-12 ms).

	Non-selective	Slab-select (single ESP)	Slab-select (dual ESP)
Measured T2 of ~10ms Gd soln.	9.57	9.86	9.68
Measured T2 of ~30ms Gd soln.	30.56	30.55	30.44
Meas. T2s in overlapping ROI	9.04/31.53	10.8/32.65	10.66/35.83
SNR of 1st echo for 10ms Gd	166	148	130
SNR of 5th echo for 10ms Gd	21	5	18

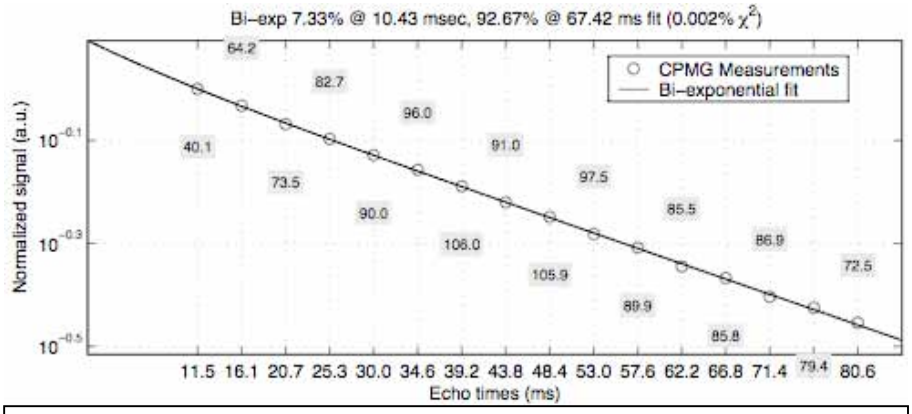

Figure 2. Decay curve from white matter ROI acquired by the slab-selective dual echo-spacing sequence (1st echo at 11.52ms, 4.6 ms subsequent spacing), and biexponential analysis. SNRs are denoted below/above each measurement.

References: [1] Poon et. al. *J Magn Reson Imaging*, 1992;2:541-553. [2] Mitsouras et. al. *in Proc. 11th ISMRM*, Toronto, Canada, 987 (5/2003). [3] Mugler et. al. *in Proc. 12th ISMRM*, Kyoto, Japan, 695 (5/2004).