Minimizing Echo Time Dependence in the Assessment of Perfusion Parameters from Multi-Echo T1-T2* Sequences

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Introduction

Contrast-enhanced T_1-perfusion imaging has long been used to assess the hemodynamics of tumors[1] and also the myocardial perfusion status[2]. Recently there has been a growing interest in the use of a combined or inter-leaved T_1-T_2* pulse sequence since the T_2* can effectively evaluate myocardial viability[3]. It has been shown that the T_2* recovery when measured at the maximum T_1-intensity during bolus passage can be used to map myocardial infarction. Since this method uses either T_1-T_2* interleaved[3] or dual echo approach, the chosen echo time (TE) for a T_2^* weighting directly affects the resulting assessment. Here we explore a multi-echo approach which is not sensitive to the TE chosen and provides consistent percent recovery information relative to the maximum T_1-intensity signal.

Method

Imaging: Imaging was performed on a 1.5T Philips Eclipse scanner equipped with echo-planar gradients. Data was obtained from *ex-vivo* dog hearts that were perfused with a continuous perfusion pump using a commercially available, assinguinous, machine perfusion solution (KPS-1, Organ Recovery Systems, Des Plaines, IL) modified by the addition of glucose (100mg/dl), insulin(10U/I) and fructose 1,6 bispphosphate (10 mmol/l). Continuous coronary perfusion was performed at 15mmHg, P02 300-400mmHg and 4^{o}C to support aerobic metabolism. Short axis images were obtained using an 8-echo spoiled gradient echo sequence with TE from 4.5ms to 36ms (spacing 4.5ms, TR = 42ms, flip 30º, BW 42kHz). Image resolution was 100×256 at a FOV of 12.5cm×16cm. The temporal resolution for single slice acquisition was 4.2ms. Gd-DTPA (0.2mmol/kg) was injected as a bolus into the aortic perfusion line after acquisition of 4 baseline frames.

Data Analysis: The signal intensity from the multi-echo images were fitted to a simple exponential curve $SI(TE) = SI_0 \cdot exp(-TE/T_2^*)$ to get both T_2* value and SI_0 (signal intensity at time zero) on a pixel-by-pixel basis. SI_0 is indicative of the T_1 signal intensity with minimal or no T_2* effect[4]. T_2* values were obtained on a pixel by pixel basis at every temporal point using different lengths of the echoes from 3-8. Six sets of T_2* values were computed using just the first three echoes (max TE 13.5ms), the first four echoes (max TE 18ms) and so on up to eight echoes (max TE 36ms). A percentage recovery of T_2* signal at the maximum T_1 signal intensity (PR)[3] was calculated as $PR = SI_t / SI_p * 100\%$ and a similar calculation was done for the T2* value ($PR = T_{2t}^* / T_{2p}^* * 100\%$) where SI_t is the T_2* signal intensity, T_{2t}* is the T_2* value when T_1 signal intensity reaches its maximum, SI_p is the average value of the signal intensity from the first four points prior to bolus injection, and T_{2p}^* is the average value of the first four T_2^* values. A comparison of the percentage recovery (PR) from both the methods was performed using the respective values from the different maximum echo times.

Results

The time intensity curves starting from a TE of 13.5ms to 36ms are shown in Figure 1 along with the T_1 signal intensity curve (SI_0). Note that at the maximum T_1-signal intensity the PR would be different for different TEs with the PR decreasing with increasing TE. At the maximum of T_1 signal intensity the T_2* signal recovery could vary from 36% to 81% depending on selected TE as shown in Table 1. On the contrary, when the computed temporal T_2*-values are chosen, the calculated PR has little effect on the TE chosen. Figure 2 shows a T_2* curve fitted using 3 echoes and 8 echoes. T_2* fitting with a shorter maximum TE (13.5ms) is more noisy as expected, but compared to the signal intensity time-curves which exhibit some T_1 effects (as shown in Figure 1), the computed T_2* curve provides the same information as the one with more echoes with a maximum TE of 36ms.

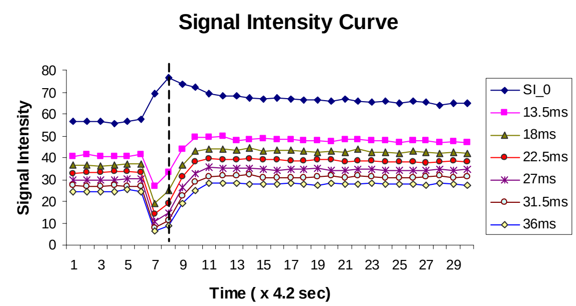

Figure 1. T_1 signal intensity curve and T_2^* signal intensity curve with TE varied from 13.5ms to 36ms. Dotted line aligns the point at maximum T_1 signal intensity.

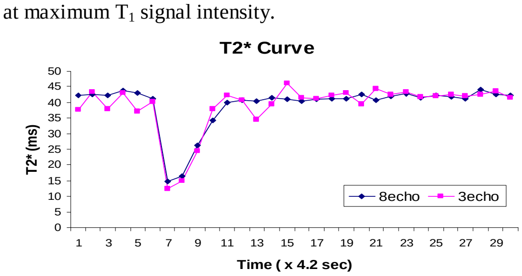

Figure 2. T_2* time curve fitted by 8 echoes (TE: 4.5ms – 36ms) and 3 echoes (TE: 4.5ms – 13.5ms).

Conclusion

Comparison of data from various groups using different TEs to determine PR should be treated with caution. PR depends on the TE chosen and hence the extent of myocardial infarction calculated could be variable. More consistent results could be obtained by converting the data to T_2* values at each temporal point. Many groups have reported data using dual echo sequence where the second echo is delayed (15ms or more) compared to the first echo which is usually at about 2ms. We suggest the use of a multiple-echo (greater than two) which will provide a better fit to the T_2* value while at the same time providing a better estimate of the corrected T_1-signal intensity. Further this can be achieved without loss of temporal resolution.

Percentage recovery (PR)	TE (ms)					
	13.5	18	22.5	27	31.5	36
T_2* Intensity curve	81%	68%	57%	48%	42%	36%
T_2* curve	37%	38%	37%	37%	38%	38%

Table 1. The percentage recovery for T_2* intensity curve and T_2* value curve.

Reference:

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[4] Kim EJ, etc. MRI 2004; 307-314.