Linear Combination Filtering Long-T_2^* Suppression in Ultra-short Echo Time (UTE) Imaging

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Introduction:

Ultra-short echo time (UTE) imaging is a very useful technique that can image otherwise invisible short-T_2 species [1,2]. Long-T_2 species dominate the images and must be suppressed to visualize the short-T_2 species. Linear combination (LC) filtering is a method of suppression that has been used to suppress ranges of T_2 values by combining images with different echo times (TEs) [3-6]. Subtracting a later echo from an earlier echo is the simplest form of LC filtering and is often applied to UTE images [2,7]. In this work we have combined UTE imaging with LC filtering to suppress long-T_2^* species.

Methods:

UTE images are T_2^*-weighted since a gradient-echo readout is used. LC filtering weights images of varying TEs and combines them to produce images with desired passbands and stopbands of T_2^* values. A convex optimization algorithm is used to determine the echo times and weights that maximize the signal-to-noise ratio (SNR) in the passbands.

We chose to create a filter that had a passband up to $T_2^* = 1$ ms, and 10^{-2} stopband suppression. We limited the TEs to be between 68 μs and 17 ms. Longer TEs will produce poor images due to T_2^* effects, and this is the maximum used in other UTE studies [8]. The resulting TEs were 68 μs, 1.8 ms, 10 ms, and 17 ms, with corresponding filter weights of 0.65, -0.70, -0.18, and 0.24. The T_2^* filter profile is shown in figure 1.

Experiments were performed on a GE Excite 1.5T scanner.

Results:

Also shown in figure 1 are experimental results for manganese chloride bottle phantoms using the LC filter. They agree very well, and the discrepancies are likely due to noise.

Figure 2 shows sagittal images of a volunteer knee using an extremity coil, TR = 500 ms, 5 mm slice thickness, and a total imaging time of 15 minutes. In the TE = 68 μs image **(a)**, it is hard to distinguish short and long-T_2^*s. When TE = 1.7 ms **(b),** the short-T_2^*s begin to disappear. The LC filtered image **(c)** suppresses the long-T_2^*s, such as fluid, muscle, and fat, while finer structures with short-T_2^*s are visible (see arrows). The long-T_2^* suppression is significantly better than image subtraction.

Conclusion:

LC filtering and UTE imaging can be used to suppress long-T_2^* species and highlight short-T_2^* species. This is robust to off-resonance and variations in RF amplitude, and inherently suppresses fat ($T_2 \approx 80$ ms). The suppression is strong and can highlight other ranges of T_2^* as well. There is potential for motion between images and significant imaging times if different TEs are acquired separately or eddy current contamination if acquired in one acquisition. There are also some artifacts related to susceptibility in the gradient-echo. This technique is a significant improvement over image subtraction and is very adept at suppressing long-T_2^* species in UTE images.

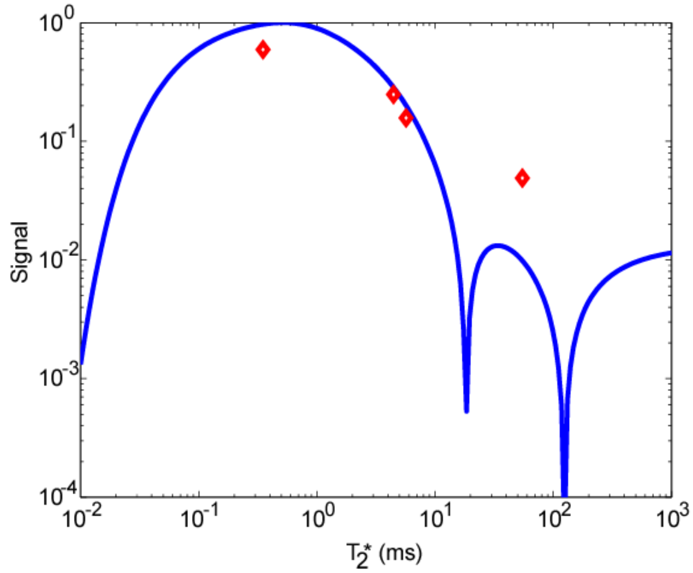

Figure 1: The solid line is the Linear Combination T_2^* filter profile and the red diamonds are experimental data from $MnCl_2$ phantoms.

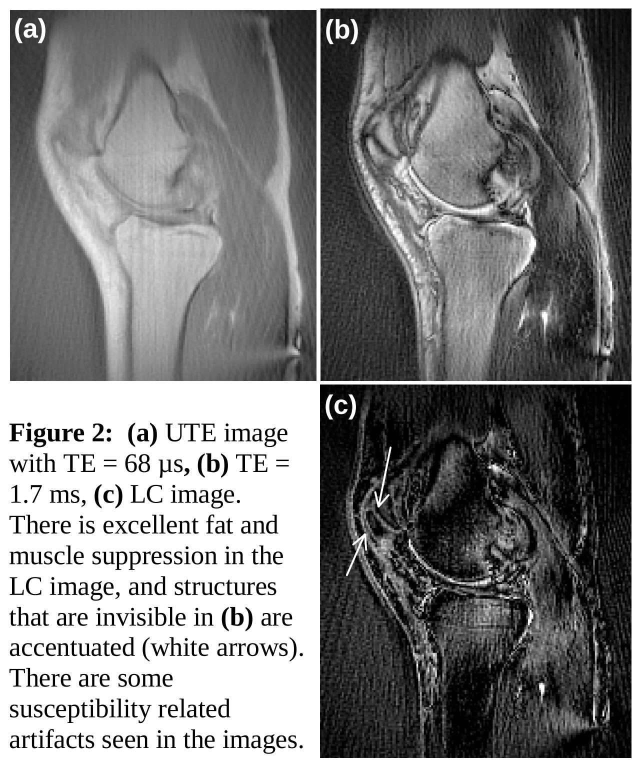

Figure 2: (a) UTE image with TE = 68 μs**, (b)** TE = 1.7 ms, **(c)** LC image. There is excellent fat and muscle suppression in the LC image, and structures that are invisible in **(b)** are accentuated (white arrows). There are some susceptibility related artifacts seen in the images.

References:

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