Quantitative Study of changes in multi-parametric MRI markers post-laser interstitial ablation therapy (LITT) for epilespy

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Target audience: Neuro-oncologists, neuro-surgeons, MR image analysis researchers, epilepsy researchers.

Purpose: In this work, we quantitatively evaluate changes in multi parametric MRI (MP-MRI) imaging markers (T1-w, T2-w, T2-GRE, T2-FLAIR, and ADC) over the epileptogenic foci, pre- and post- laser interstitial thermal therapy (LITT), to (a) identify MR imaging markers that change most-dramatically over time while computing treatment related changes post-LITT, and (b) develop a weighted temporal MP-MRI signature corresponding to successful / unsuccessful treatment, by combining the imaging markers identified as most contributory in evaluating treatment related changes at different time points post-LITT, in a cohort of epilepsy patients. Minimally invasive MRI-guided LITT is a recent alternative to traditional craniotomy for epilepsy patients, but currently is only practiced as an investigational procedure at a few centers worldwide, due to the limited knowledge of its effects on the ablated epilepsy zone post-treatment [1, 2].

Methods: Two epilepsy patients were monitored at regular intervals (24-hour, 1-month, 3-months) post-LITT via MP-MRI (T1-w, T2-w, GRE, FLAIR, and ADC) as a part of an ongoing study between 2011-2012, after initial 3-Tesla pre-LITT MP-MRI. Our framework consists of following steps: In Step 1**,** a 3D affine registration is implemented via the Slicer software 4.1. to accurately align post–LITT MRI with reference to pre-LITT MRI sequences at every time–point $t_k, k \in \{1, ..., n\}$, n is the total number of time points evaluated post–LITT, for every MRI protocol. After spatial alignment between pre and post-LITT images, in Step 2**,** a differences map is computed at every voxel by computing an absolute difference of imaging markers (T1-w, T2-w, FLAIR, GRE intensities, ADC values). Individual difference maps, for each protocol, allow for quantification of changes in imaging markers across each of the individual protocols. A weighted MP–MRI map is obtained in Step 3 by leveraging difference maps for every protocol, by computing a weighted combination of relative contribution of individual imaging markers in quantifying treatment changes, at every time point, $k, k \in \{1, 2, .., n\}$ [3]. In Step 4, we develop a time dependent MP–MRI map as $\delta_{int} = [\mu_1, ..., \mu_n]$, by concatenating mean intensity (μ_k) changes within the ablation zone in at every time point k.

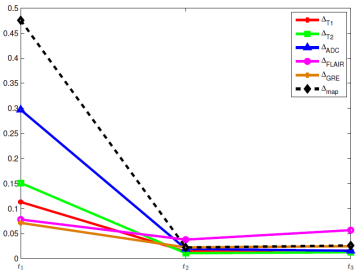

Fig 1(a) μ_k at t_1,t_2, t_3 for T1, T2, GRE, FLAIR, ADC, MP-MRI map.

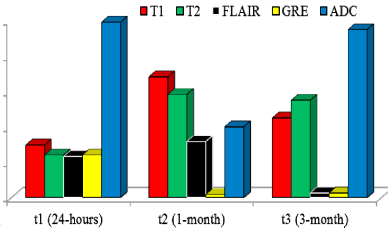

Fig 1(b) Average contributions of individual protocols for t_1, t_2, t_3

Results and Discussion: Figure 1(a) shows different time-dependent profiles (normalized between 0 and 1) created for each of the protocols by plotting μ_k at every time point for patient 1. Similar trends were obtained for patient 2. Trends in Fig. 1(a) suggest that, (a) mean intensity differences consistently decrease over all protocols for patients with successful treatment, and are substantially reduced between 1 and 3 months as compared to that within the first 1-month, and (b) ADC changes most dramatically over time compared to T2-w, T1-w, GRE, and FLAIR protocols. Based on clinical findings [2], the exaggerated changes in MP- MRI markers during the first one month may be attributed to edema and swelling caused due to the treatment. Figure 1(b) illustrates the contributions of each protocol (normalized between 0 and 1), over the two studies for different time points. Figure 1(b) reflects that, ADC is consistently identified as the most important protocol immediately post- LITT (24-hours), while a combination of T1-, T2-w, and ADC was identified as most contributory in identifying changes after 24-hours post-LITT. A time dependent MP-MRI temporal signature is obtained by combining weights computed for each protocol (Fig 1(b)) and is shown as a dotted black line in Fig 1(a).

Conclusion: A novel quantitative image analysis framework for evaluating MP-MRI marker changes post-LITT on a per-voxel basis was presented, to (a) identify MRI markers that change most-dramatically over time post-LITT, and (b) create an optimal MP-MRI signature (by selectively combining MRI protocols that were deemed contributory) to investigate MP-MRI markers relating to post-LITT changes, and potentially distinguish successful from unsuccessful treatment.

References: [1] Tllez, J. et al., Epilepsy Research (2010). [2] D. Curry et al., Epilepsy and Behavior (2012). [3] Tiwari, P. et al., NMR Bio (2012).