

Multi-spectral Quantitative Regional MRI Analysis in Patients with Temporal Lobe Epilepsy

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Introduction

Temporal Lobe Epilepsy (TLE) is a group of brain disorders typified by periodic seizures that occur in one or both temporal lobes in the brain. While patients with TLE are treated with anti-epileptic drugs, approximately 20% of the cases are drug resistant¹, making them eligible for temporal lobectomy surgery. Prior to the procedure, patients undergo an MRI study where a radiologist looks for abnormalities in the temporal lobe. In many cases radiological findings are negative. In this case, intracranial EEG monitoring maybe required determining the extension of the temporal lobe involved in the seizures. The goal of this work is to extract regional metrics from pre-operative MR images and to statistically compare them for each patient against a control group of normal subjects. The selected metrics are based on subregional intensity changes and volumetric differences². For every subject in the study we obtain four quantitative MR maps: T1, T2, Fractional Anisotropy (FA) and Mean Diffusivity (MD). We proceed to statistically compare each patient map with the respective control group maps for each one of these metrics, correcting the results for the effect of multiple comparisons using the Bonferroni correction. Statistically abnormal regions (volume, intensity) were reported individually for every patient.

Methods

Patients (n=10) participating in this study were pre-surgically imaged using a 3T MR scanner (GE Discovery MR750) with DESPOT1 and DESPOT2³ fast T1 and T2 mapping sequences (1mm isotropic), as well as with a DTI sequence (41 directions, 2.5mm isotropic). Based on prior radiological examinations, 5 patients were classified as MR positive (MR+) and 5 patients were MR negative (MR-) for TLE. 20 normal subjects were scanned with the same protocol and constituted the control group. A region-based analysis was preferred over voxel-based analyses since the latter relies on volumetric registration which is inherently inaccurate in cortical regions. Synthetic T1-weighted images were generated from the T1 maps and used in FreeSurfer⁴ to extract cortical and sub-cortical regions. These regions were derived from surface-based atlas registration for every subject. After co-registering the DTI images (FA,MD) and the T1 and T2 maps to the image space defined by the T1 map, the region labels were used to extract the volume, and mean intensity of each region, as well as the difference in volume and intensity between corresponding structures in the left and right hemispheres (for example, left and right hippocampus). The difference in intensity was measured as the result of a two-sample Kolmogorov-Smirnov test between the image intensities of the left and right lobes. These metrics were obtained in all four images (T1,T2,FA,MD) for all the subjects in the study. Each patient was compared with the control group using a single case t-test⁵ with an alpha threshold of 0.05 (uncorrected) which was corrected posteriori using the Bonferroni correction. The results were validated using a leave-one-out cross-validation technique.

Results and Discussion

The above method detected abnormal regions in all four image spaces (T1, T2, FA, MD). A significant number of temporal lobe abnormalities consistent with TLE radiological findings were identified. In the temporal lobe (Figure 2a) the average number of detected abnormalities was the highest for the MRI+ patients, followed by MR- patients and then controls. Most of the temporal lobe abnormalities for both MR+ and MR- patients were reported by the MD map comparisons. In contrast, very few abnormalities were found in the T2 map for both MR+ and MR- patients. The analysis was extended to the rest of the brain where additional abnormal regions were identified (Figure 2b). Our approach demonstrated that the average of abnormal regions for controls and MR- patients outside of the temporal lobe was low (less than one per-subject and per-image). The superiotemporal white matter region was reported as the most abnormal region across the sample (n=9). The second most abnormal region was the middle temporal white matter region (n=7), followed by the amygdala (n=6) and the hippocampus (n=6), all four of these structures belonging to the temporal lobe.

Conclusion

The current standard neuroradiological protocol for the assessment of TLE in MR images is based on the analysis of abnormal changes in volume and signal intensity in T1-weighted and T2-weighted images. We extended this analysis to a multi-spectral scenario where volume and signal intensity metrics were obtained from four different MR maps (T1, T2, FA, MD). The method successfully identified abnormal regions that were consistent with TLE for both MR- and MR+ patients. The multi-factorial aetiology of TLE suggests that combining information from different MR quantitative maps could provide more information about the structural changes in the brain caused by this disease. These changes are not always evidenced in the T1-weighted and T2-weighted images that are clinically used for TLE diagnosis. The results presented in this work suggest that there is a synergistic effect when combining information from T1, T2, FA and MD maps for the purpose of studying the effects of TLE in the brain. An early identification of abnormal regions on a multi-spectral MR quantitative imaging approach could potentially make EEG monitoring more selective and if temporal lobe surgery is required, the immediate identification of these regions could lead to a less invasive surgery planning protocol.

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[3] Deoni. J Magn Reson Imaging (2009) vol. 30 (2) pp. 411-7

[4] FreeSurfer Image Analysis Suite (<http://surfer.nmr.mgh.harvard.edu/>)

[5] Crawford J. et al, Neuropsychologia (2009) 47:p 2690-2695

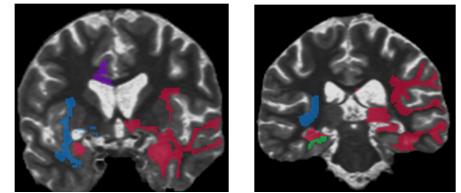


Figure 1: Results from a MR+ TLE patient with mesial temporal sclerosis. Green = T1, Blue = T2, Purple = FA, Red = MD. The amygdale, right hippocampus and right parahippocampal gyrus appeared to be abnormal as well as some regions in the temporal white matter on both hemispheres.

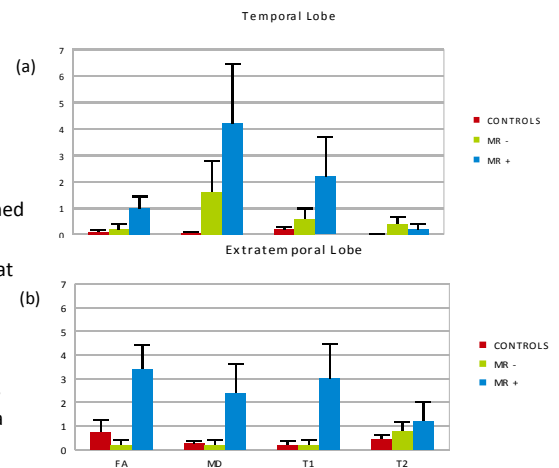


Figure 2: Average of abnormalities found per-subject and per-image. Error bars represent the standard error of each average a) Temporal Lobe b) Non- temporal lobe abnormalities