Texture Analysis of MRI Assists in the Detection of Focal Cortical Dysplastic Lesions

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Background. Focal cortical dysplasia (FCD) is a frequent cause of medically intractable partial epilepsy of extra-temporal lobe origin. MRI characteristics of focal cortical dysplasia include cortical thickening, poor distinction between gray and white matter transition, and white matter abnormalities such as clusters of abnormal neurons. In many cases, FCD can be detected on MRI, facilitating improved surgical seizure control. However, MRI still fails to identify a lesion in half the patients with partial epilepsy of extra temporal origin. Histological examination of tissue removed at surgery in most of these patients demonstrates FCD.

The reason for the failure of MRI to show these lesions is that they are too small and too subtle to be detectable by standard radiological analysis. We hypothesized that MRI texture analysis [1] could increase the sensitivity of high-resolution MRI for detecting subtle dysplastic lesions.

Study design and data analysis. Patient selection. We selected seven consecutive patients with partial epilepsy of extra-temporal lobe origin. All but one had a focal cortical resection for intractable seizures and histologically proven FCD. In four patients FCD was seen on MRI prior to the surgery and in three retrospectively after it was found in the tissue removed at surgery. Six patients were operated and all became seizure free.

MR acquisition. MRI images were acquired using a T1-weighted 3D gradient-echo sequence (TR 18 ms, TE 10 ms, 1 signal average, flip angle 30°, matrix 256 x 256, FOV 250, thickness 1mm). Approximately 170 slices were obtained. Images were automatically registered into stereotaxic space [2]. MR images were then automatically corrected for intensity non-uniformity [3]. The analysis was done on a Silicon Graphics workstation (Mountain View, California, USA).

Texture analysis. Preoperative MR images were normalized to 128 gray levels and segmented into gray matter (GM) and white matter (WM). We calculated six first-order texture features modeled on MRI characteristics of FCD. The six features were: cortical thickness (the total number of consecutive GM pixels in all 3 dimensions), absolute gradient [1], variance of gray levels [1], GM infiltration (percentage of GM pixels in a neighborhood centered on a WM pixel), GM/WM ambiguity (m-x)/m, where m is the midpoint between the peak GM and WM intensities and x is pixel intensity), and relative gray level (g-x)/g, where g is the peak GM intensity and x is pixel intensity). Each feature was calculated over a neighborhood for each pixel in the MRI volume, and thus we were able to create six feature volumes for each patient. It was visually determined that a feature based on the ratio of cortical thickness to gradient was most effective at locating FCD lesions. This particular feature volume was used for the rest of the analysis.

Results. Lesions were visually observable in the feature volume for 7/7 patients, compared to 4/7 on the pre-operative MRI. Figure 1 shows two representative examples.

Discussion. FCD lesions were obvious on feature volumes for 7/7 patients compared to 4/7 on pre-operative MRI. Thus texture analysis enhanced visual detection of FCD.

Further directions include performing high-resolution MRI using a surface coil on regions of the brain identified as containing lesions by first-order texture analysis. High-resolution imaging should enable us to utilize second-order texture methods to achieve more complete localization and gain further insight into the pathology of dysplastic lesions. The relatively small size of FCD lesions necessitated the use of small pixel neighborhoods; thus it was unfeasible to calculate a co-occurrence matrix, which is necessary for second-order texture analysis.

Conclusion. Texture analysis of MRI improves visual detection of focal cortical dysplasia, even in cases where no lesions were obvious in pre-operative MRIs. Preliminary evidence demonstrates utility for eventual automated segmentation. This technique could considerably increase the number of patients with so-called "non-lesional" partial epilepsy who could benefit from surgery.

References