Quantitative Imaging of Cortical Abnormalities in Extratemporal Epilepsy

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AIM: Epilepsy is often associated with focal cortical abnormalities. We investigated the use of cortical thickness mapping for objective and quantitative imaging of cortical abnormalities in epilepsy subjects using structural MRI. We use this technique to characterize cortical abnormalities that have been identified by radiological inspection in five epilepsy subjects. Cortical thickness mapping may be a useful tool for the quantitative analysis of structural differences in epilepsy brains.

METHODS: Five subjects with extratemporal epilepsy and twenty age-matched controls were scanned on a Siemens TIM Trio MR scanner with the following imaging parameters: 0.9 mm isotropic voxel size, T1-weighted MPRAGE whole brain scan. The epilepsy subjects had a range of visually identified cortical abnormalities (2 glioma, 3 focal cortical dysplasia). Lesions were manually delineated in the epilepsy subjects. Gray matter cortical thickness was measured voxel-wise using software developed by the Australian e-Health Research Centre, CSIRO [1]. The epilepsy subjects and controls were co-registered using non-rigid registration software ANTS (http://www.picsl.upenn.edu/ANTS/). Symmetric normalization diffeomorphic mapping was used to warp images. A custom template was constructed using ten randomly selected control structural MR scans. The warp mapping the structural MRI for each control to the template was estimated and applied to the control's thickness image. These thickness images were averaged to produce control mean and standard deviation thickness images in template space. The warp mapping each epilepsy subject's structural MRI to the template was generated and the inverse of this warp applied to the control mean and standard deviation thickness images to move these maps to the epilepsy subject's native space. Finally 4mm Gaussian smoothing was applied to the individual's thickness map and the control mean and standard deviation images. The voxel-wise difference between each epilepsy subject and the control group was measured using the z-score

$$z = \frac{x - \mu}{sd}$$

where x is the individual's cortical thickness, μ is the control mean and sd is the control standard deviation. Thresholds for the identification of abnormal cortex were measured empirically by determining the z-score at which the number of voxels external to the manually delineated lesion reduced by 95% and 99%, averaged across the five epilepsy subjects.

RESULTS: Visual inspection of individual cortical thickness maps in the epilepsy subjects showed increased cortical thickness co-located with the lesion in all five subjects. Figure 1 shows an axial slice of the structural MRI scan and the overlaid cortical thickness map in an example epilepsy subject. Thresholds for abnormal cortex were determined to be z = 5.27 (95% reduction in voxels outside the lesion) and z = 8.10 (99% reduction in voxels outside the lesion), as shown in Figure 2. The thresholds allowed objective detection of cortical abnormalities by comparing the individual's cortical thickness with the control group voxelwise. The thresholded z-score maps are shown in Figure 3, overlaid on the same subject from Fig 1.

DISCUSSION: Cortical thickness analysis of structural MRI is able to localize a variety of cortical abnormalities in extratemporal epilepsies. The method may be a useful technique for quantitative, objective analysis of structural changes in epilepsy brains.

REFERENCES: [1] Acosta, O., Bourgeat, P. et al, Automated voxel-based 3D cortical thickness measurement in a combined Lagrangian-Eulerian PDE approach using partial volume maps, Medical Image Analysis 2009: 13 pp 730 – 743

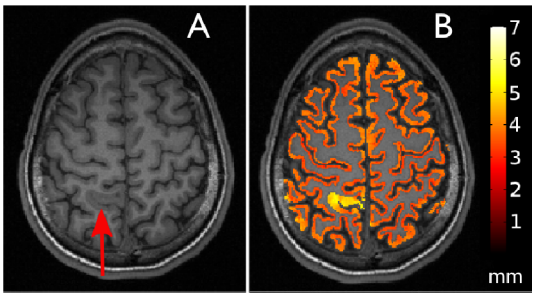

Figure 1. A. Axial slice of epilepsy subject with lesion indicated by red arrow. B. Cortical thickness map overlaid on structural MRI. Regions of high thickness are "hotter".

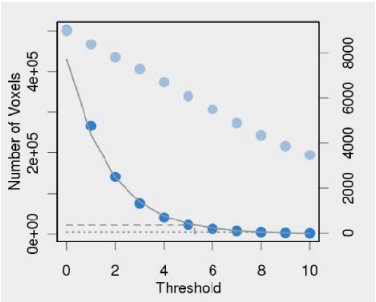

Figure 2. The number of voxels exterior to lesion (dark blue, left axis) and co-located with the lesion (light blue, right axis) as a function of threshold (z score), averaged across all epilepsy subjects.

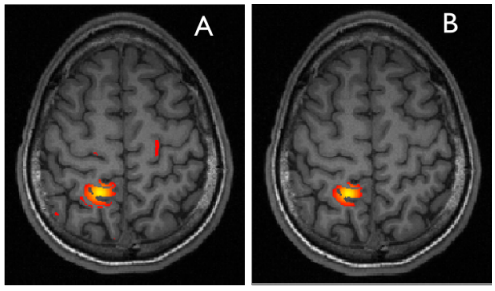

Figure 3. Thresholded z score maps showing objective localization of thickened cortex (A. moderately strict threshold z = 5.2, B. strict threshold z = 8.1)