Measuring Cortical Thickness in Brain MRI Volumes to Detect Focal Cortical Dysplasia

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Description of the problem

Nowadays the prevalence of epilepsy is estimated to be around 1% of the population where up to 40% of the patients continue to have seizures despite optimal drug treatment [1]. In patients with drug refractory epilepsy, approximately one-half suffer from localized malformation of cortical development known as *focal cortical dysplasia* (FCD). There, the epilepsy surgery can yield a high chance of seizure freedom, even up to 80%. However, despite the increased quality of the magnetic resonance imaging (MRI) which is often used in diagnosis of the FCD, lesion identification remains a very difficult task. Strikingly, the clinical experience suggests that this type of lesions can be missed in the initial evaluation in up to 35% of the cases. This is mainly due to a combination of factors including a possibly subtle lesion, the complex convolution of the human cerebral cortex and the dependence on the expertise and attention of the radiologist viewing the MR images. Among others, one of the main cortical anomalies observed in the FCD pathology is focal thickening of the cortex. This manifestation of the disease looks for the algorithms able to detect the changes of the cortical thickness. In the present work, we propose a new algorithm for cortical thickness measurement in T1 weighted (T1-w) MRI images aiming to overcome the major limitation of a number of the existing similar methods which could lead to under- or over-estimated thickness of grey matter within sulci: (1) lack of awareness of the partial volume (PV) effect (the presence of multiple tissue classes in a single voxel) present at both the white matter (WM) to gray matter (GM) and the GM to cerebrospinal fluid (CSF) transition, and (2) ignorance of the regions of buried cortex where the CSF between the sulci is not resolved.

Methods

Inspired by the work of Thorstensen *et al.* [2], we propose to estimate the thickness of the cortex by fitting spheres into the gray matter mantle of the brain such that the amount of probability-weighted gray matter that is contained in each sphere is maximized. As illustrated in Fig. 1, the thickness measurement starts by preparing an original T1-w brain image: removing the skull, removing the bias field, and volume interpolation; and continues with estimation of the three PV maps: GM, WM and CSF map. Then, in each voxel whose probability in the GM PV map is above a given threshold (e.g. larger than 0.9), a set of spheres with different radii are centered and the sums of the weighted posterior probabilities over all sub-voxels contained in a sphere are computed. Finally, we select the sphere that contains as much GM and as little WM and CSF as possible and take the radius of that sphere as the thickness of the cortex at a given voxel.

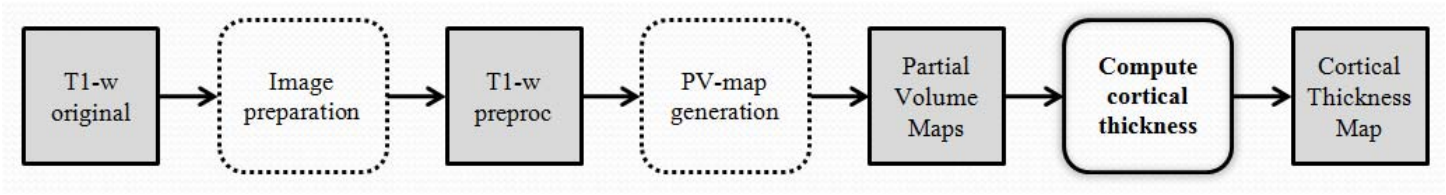

Fig. 1. Flow chart of the proposed cortical thickness measurement

Results & Discussion

The set of ten T1-w MRI patient scans are used to test the ability of the method to identify regions of the cortex with increased thickness which would suggest increased probability of the FCD lesion in that area. In 8 out of 10 patients, the FCD lesion area had a visibly higher value on the thickness maps than the surrounding tissue. In comparison, the thickness maps obtained by the method of Freesurfer [3], a well-recognized tool in the brain MRI imaging, pointed to only 5 of the 10 FCD lesion areas.

Compared to the approach from Ref. [2], one important benefit of our method comes from the fact that the thickness is estimated in not only the voxels of the central axis between the inner and outer surface of the cortex but in all voxels having high probability of belonging to the cortex. This prevents the error of under- or over-estimation of the thickness in a given area potentially coming from either miss-selection of the central voxel of the sphere or certain localized imaging artifacts influencing the PV maps.

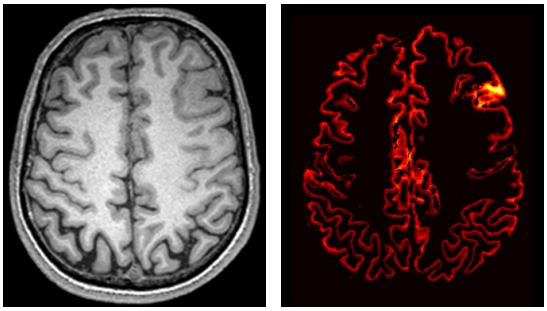

Fig. 2. Example MRI data: (a) original T1-w slice, (b) cortical thickness map.

Conclusions

The success rate in the early experiments with FCD patient data is very promising. In the future, we will work in multiple directions to improve the specificity of the technique: using multi-modal image information (T1-w and FLAIR), improving the PV segmentation, better sulci detection, incorporating restrictions determined by anatomical characteristics of the cortex.

References

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