

Title

Multi-modal measurement of cortical thickness in brain MRI for Focal Cortical Dysplasia detection

Authors & Affiliation

Kumcu A, Platisa L, Despotovic I, Vansteenkiste E, Pizurica A, Deblaere K, and Philips W
TELIN-IPI-IBBT, Ghent University, Ghent, Belgium,
Department of Neuroradiology, Ghent University Hospital, Ghent, Belgium

Synopsis

In this work we aim to improve the detection of Focal Cortical Dysplasia on MRI images using a multimodal approach. We propose to estimate the thickness of the cortex jointly using partial volume maps of T1-weighted MPRAGE and T2-weighted FLAIR images by fitting spheres into the gray matter of the brain such that the amount of probability-weighted gray matter contained in each sphere is maximized. Results on nine patients show that the FCD lesions for all patients could be detected using the multimodal approach compared to T1 alone (FCD detected in only 7 patients) and Freesurfer (4 patients).

Description of the problem

Focal cortical dysplasia (FCD) is a disease of the brain caused by malformations during cortical development and is found in approximately one-half of patients with drug refractory epilepsy. Epilepsy surgery can render many of these patients seizure-free but depends on accurate identification and delineation of the lesion. Magnetic resonance imaging (MRI) is typically used to diagnose FCD, but clinical experience suggests that FCD lesions can be missed in the initial evaluation in up to 35% of the cases. This can be due to a combination of factors including the presence of subtle lesions, the complex convolution of the human cerebral cortex, and the dependence on the expertise and attention of the radiologist viewing the MR images. Algorithms that are automatically able to detect these abnormalities may be able to decrease the number of missed cases. Features of FCD on MR images include localized cortical thickening and blurring of the gray/white matter junction in T1-weighted (T1-w) images, and increased signal on T2-weighted (T2-w) or fluid attenuated inversion recovery (FLAIR) images [1]. Previous work in automatically detecting FCD and measuring cortical thickness has often focused on the processing of T1-w images [2,3]. In this work, we apply a recently proposed cortical thickness measurement algorithm [3] in a multi-modal fashion using both T1-w and T2-w FLAIR images. The multi-modal approach aims to overcome the limitations of uni-modal (T1-w) methods which may lead to an underestimation of the gray matter thickness in subtle FCD cases. The increased signal seen on T2-w FLAIR sequences in the region of the FCD lesion [1] can offer additional information. Another advantage of this method includes its awareness of the partial volume (PV) effect (presence of multiple tissue classes in a single voxel) present at the white matter (WM) to gray matter (GM) and the GM to cerebrospinal fluid (CSF) transitions.

Methods

Inspired by the work of Thorstensen et al. [4] and Platisa et al. [3], we propose to estimate the thickness of the cortex jointly using T1-w MPRAGE and T2-w FLAIR images by fitting spheres into the gray matter of the brain such that the amount of probability-weighted GM contained in each sphere is maximized. Fig. 1 shows the pipeline used to process the MRI scans. The following steps are applied to the scans in parallel: skull removal [5], volume interpolation, bias-field removal and PV estimation [6] to generate GM, WM, and CSF maps. Then, in each voxel whose probability in the GM PV map is above a given threshold, 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. 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. The T1-w and T2-w FLAIR cortical thickness maps are weighted and combined to give one thickness map.

Results & Discussion

A set of nine patients who underwent both T1-w and T2-w FLAIR scans have been used to identify regions of cortex with increased thickness, which would suggest increased probability of the FCD lesion in that area. For T1-w images, the FCD lesion area had a visibly higher value on the thickness maps than the surrounding tissue in 7 out of 9 patients. In the remaining 2 patients, cortical thickness measurements on the T2-w FLAIR images showed clear thickening in the region of the FCD, resulting in 100% detection using both images. The results show a clear benefit of the multi-modal approach over the uni-modal approach. In comparison, the T1-w thickness maps obtained by Freesurfer [7], a well-recognized tool in the brain MRI imaging, found lesions in only 4 of 9 patients.

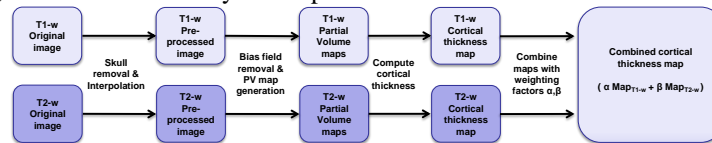


Figure 1: Processing pipeline for cortical thickness measurement based on T1-w and T2-w MRI images. Final map is generated by weighting cortical thickness maps of T1-w and T2-w images.

Conclusions

These results show promise in the use of multi-modal methods for FCD detection. In the future, we will look into ways of improving the specificity of the technique: better incorporation of multi-modal information (T1-w and T2-w FLAIR), improving the PV segmentation, better sulci detection, incorporating restrictions determined by anatomical characteristics of the cortex.

- [1] Deblaere K, and Achten E, Structural magnetic resonance imaging in epilepsy, *European radiology*, 18(1):119-29, 2008.
- [2] Antel S B, Bernasconi A, Bernasconi N, Collins DL, Kearney RE, Shinghal R, and Arnold DL, Computational Models of MRI Characteristics of Focal Cortical Dysplasia Improve Lesion Detection, *NeuroImage*, 17, 1755-1760, 2002.
- [3] Platasa L, De Smet A, Despotovic I, Kumcu A, Vansteenkiste E, Pizurica A, Deblaere K, and Philips W, Measuring Cortical Thickness in Brain MRI Volumes to Detect Focal Cortical Dysplasia, *Proc. Intl. Soc. Mag. Reson. Med.* 19, 2011.
- [4] Thorstensen N, Hofer M, Sapiro G, and Pottmann H, Measuring cortical thickness from volumetric MRI data, *Geom. Prep.* 170, Vienna Univ. of Technology, 2006.
- [5] Smith SM, Fast robust automated brain extraction, *Human Brain Mapping*, 17(3):143-155, November 2002.
- [6] Zhang Y, Brady M, and Smith S, Segmentation of brain MR images through a hidden Markov random field model and the expectation maximization algorithm, *IEEE Trans. on Medical Imaging*, 20(1):45-57, 2001.
- [7] Han X, Jovicich J, Salat D, van der Kouwe A, Quinn B, Czanner S, Busa E, Pacheco J. et al., Reliability of MRI-derived measurements of human cerebral cortical thickness: the effects of field strength, scanner upgrade and manufacturer, *Neuroimage* 32(1): 180-94, 2006.