# Assessing spatial correspondence between subtle cortical dysplasias and sulcal pattern

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**Background.** Malformations of cortical development are an important cause of pharmacoresistant epilepsy and are found in about 30% of adults referred for epilepsy surgery. Focal cortical dysplasia (FCD), a malformation due to abnormal neuroglial proliferation, is the most frequent form. Clinical observations [1,2] suggest that small FCD lesions may be located at the bottom of a deep sulcus. However, the exact relationship between FCD and brain sulci remains unclear, mainly because the complexity of the brain convolution makes the visualization of sulcal-gyral patterns on MRI difficult. Our purpose was to examine systematically the spatial correspondence between small FCD lesions and sulci, including sulcal depth, using image processing.

**Methods.** We studied 43 consecutive FCD patients. In 18/43 (42%) the lesion was overlooked by initial routine clinical MRI inspection. Twenty-eight patients (28/43=65%) underwent surgery and the FCD was confirmed by histopathology in all of them. An expert observer segmented manually FCD lesions on high-resolution T1-weighted MRI (spoiled 3D gradient echo; TR=18, TE=10, voxel size 1mm$^3$) to calculate their volume (mean ± SD: 7731 ± 14891 mm$^3$; range: 128 to 94,620). We classified lesions into small and large using qualitative (visibility) and quantitative (volume) criteria. An entropy index was used to place a threshold that separated small from large lesions along their volume range. Sulci were identified and labeled automatically on MRI using an algorithm based on a congregation of neural networks [3]. FCD lesions and sulci were then visualized simultaneously in 3D. We measured the depth of the bottom line (i.e., the inner edge of the sulcus) of the sulci related to each FCD and the corresponding sulci in 21 healthy controls. We also measured sulcal depth within the lesional neighborhood, as defined by a 4 mm dilation of the FCD label.

**Results.** 21/43 (48%) patients had small FCD lesions (mean volume ± SD: 1282 ± 852 mm$^3$; volume range: 128 mm$^3$ to 3093 mm$^3$). In 18 of them (18/21=86%), the lesion had been overlooked on MRI. 18/21 (86 %) small FCD lesions were located at the bottom of a sulcus. Two others were related to the walls of several sulci and one was located at the crown of a gyrus (**Figure A-C**). Sulci related to the FCD were in average 23% deeper than the corresponding sulci in controls (maximum depth +27%; $p < 0.008$). Moreover, the sulcal portion within lesional neighborhood was in average 30% deeper than that of the entire sulcus ($p < 0.0002$).

**Conclusion.** We demonstrate that the vast majority of small FCD lesions are located at the bottom of an abnormally deep sulcus. A dichotomy between mechanical properties of the dysplastic tissue and extrinsic forces during morphogenesis may produce a local weakness in the developing cortex leading to anomalous folding. Given the low rate of visual identification of small FCD, particular attention should be paid to sulcal morphology when evaluating the MRI of epileptics with suspected dysplastic lesions. Our findings advocate for the use depth electrodes instead of subdural grids when investigating small FCD or so-called "MRI-negative" patients.

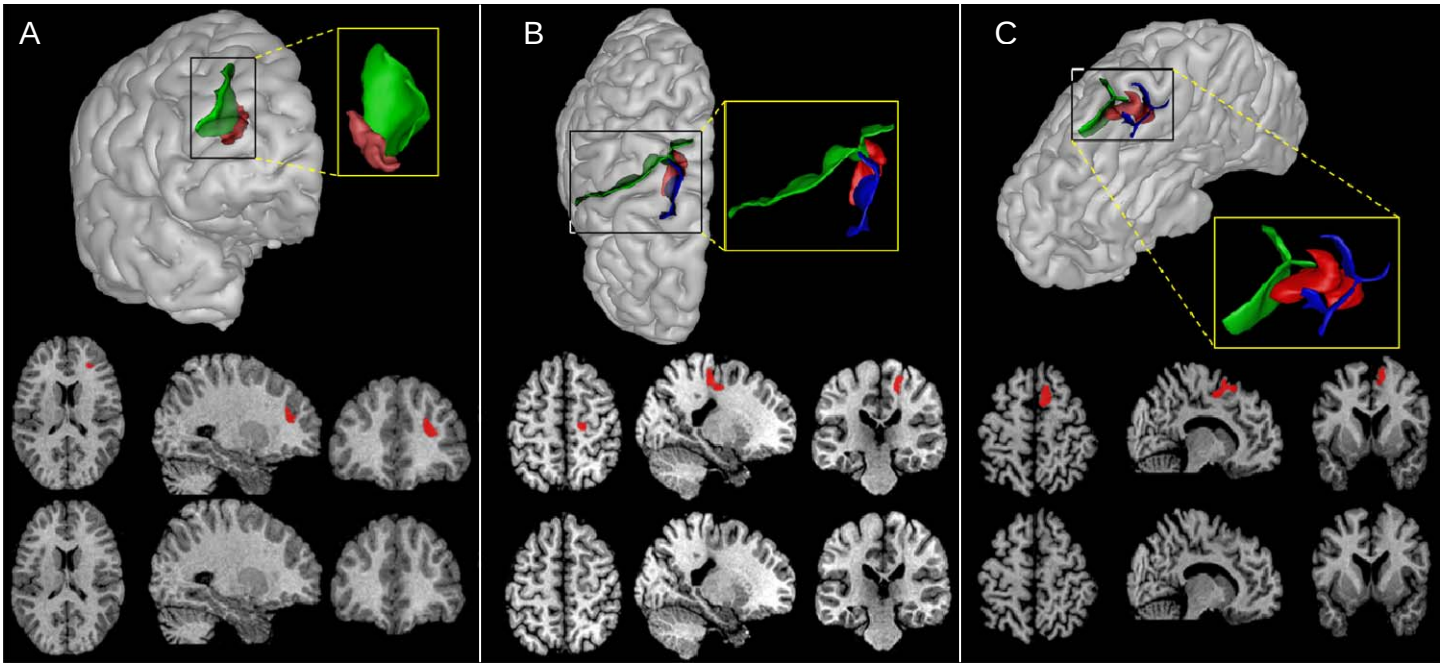


**Figure.** *Top row*: 3D surface reconstruction with overlaid sulci (green). The FCD is colored in red. Sulci related to the FCD are magnified in separate panels. Three examples are shown: A) FCD at the bottom of a sulcus; B) FCD at the bottom of two sulci; C) FCD related to the walls of several sulci. *Bottom rows:* T1-weighted MR images (axial, sagittal and coronal) overlaid with the FCD label.

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[2] A. C. Bastos et al., *Ann Neurol,* vol. 46, pp. 88-94, 1999.

[3] D. Riviere et al., *Med Image Anal,* vol. 6, pp. 77-92, 2002.