Parcellation of Cerebral Cortex based on FLAIR Signal Intensity

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Introduction**:** Heterogeneity of intrinsic gray matter signal intensity can be demonstrated on some MR sequences, particularly FLAIR. Presumably, this reflects intrinsic differences in cytoarchitectonic and myeloarchitectonic properties of cortical regions, suggesting that MR signal intensity could parcellate the cortex into anatomically distinct areas. To visualize FLAIR signal heterogeneity across the cortex and to compare this variation across subjects, we mapped FLAIR signal intensity data onto surface models obtained from coregistered T1 datasets. Furthermore, by assigning a Brodmann number to each point based on the cortical surface, we generate values for FLAIR signal intensity in each cortical area and show that this signal intensity profile is repeatable across subjects.

Methods:

Subjects: Six healthy volunteers (31±7 y) provided written informed consent to participate in this IRB approved protocol.

MRI Technique: Images were obtained at 1.5 T using a quadrature head coil. High resolution 3D IR-GRE T1 weighted images were obtained with the following parameters: TR12, TE 5, TI 250, FA 20°, BW 15kHz, FOV 22cm, matrix 256x192, slice thickness 1.2 mm, slices 124, excitations 1. Acquisition time was 6:34 per volume, 2 volumes were obtained. Acquisition resolution was 0.86x1.45x1.2 mm^3, zero-fill interpolated to 0.86x0.86x0.6 mm^3. FLAIR images were acquired using 2D fast FLAIR with TR/TE/TI = 9000/140.2200 ms, ETL 21, BW 15 kHz, FOV 22 cm, matrix 256x256, slice thickness 2.5 mm, number of slices = 56, number of acquisitions = 5, 2 NEX, echo train length = 22, time = 13:12 per volume, 5 volumes, Acquisition resolution was 0.86x0.86x2.5 mm

Surface extraction: A nonlinear uniformity correction was applied to the T1 data (N3 correction, MINC) and the two volumes were rigidly coregistered (FLIRT). Interactive extraction of isomorphic surfaces at the gray/white boundary and at the pial surface were generated with FreeSurfer.

Mapping of FLAIR signal: The five FLAIR volumes were rigidly coregistered (FLIRT, FMRIB) and resampled to match the T1 data. Landmark based adjustment of the coregistration was applied in some cases (MIPAV). For each node on the T1 surface, FLAIR signal intensity was averaged along the central portion of a line segment extending between the corrsesponding nodes on the pial and gray-white surfaces. FLAIR signal intensity was rendered onto the surface (SUMA – Figure 1).

Identification of Brodmann areas (BA): A volume of BA numbers was created by querying the VTOL database to assign each point in the volume a value corresponding to the nearest BA. Volumes were manually transformed into Talairach space, and the same transformation was applied to the surfaces. Each node was assigned a BA based on the midpoint between the nodes on the pial and gray/white surfaces.

Analysis: The preceding process resulted in assignment of a single BA and FLAIR signal intensity at each node. FLAIR signal intensity was normalized based on the mean value for each subject, and FLAIR signal intensity vs. BA was plotted.

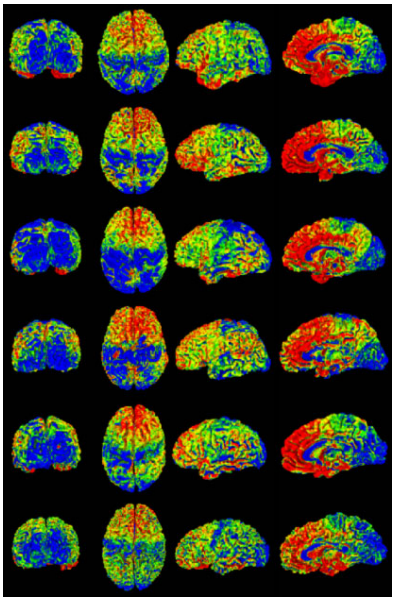

Figure 1. FLAIR signal intensity mapped onto cortical surface in six subjects (hypo- hyper intense)

Table 1. FLAIR SI (mean ± SD) in selected Brodmann Areas

	BA	Right Hemi			Left Hemi		
S1	2	1.062	±	0.017	1.055	±	0.010
M1	4	1.041	±	0.009	1.040	±	0.011
Parietal	7	1.071	±	0.015	1.051	±	0.009
Prefrontal	10	1.103	±	0.015	1.106	±	0.015
V1	17	1.047	±	0.008	1.056	±	0.020
Cingulate	24	1.146	±	0.016	1.109	±	0.021
A1	41	1.065	±	0.019	1.056	±	0.005

Results: Heterogeneity of cortical both gray and white matter was clearly evident on axial FLAIR images. Hypointense gray matter with indistinct gray white differentiation was identified in the pre and post central gyri, Heschl's gyrus, and a large portion of the occipital lobe corresponding to primary motor, primary sensory, primary auditory areas and motor cortex. The pial surfaces derived from the T1 dataset, assigned a color scale based on FLAIR signal intensity are shown in Figure 1. The pattern of FLAIR signal intensity is highly consistent across subjects. Borders between regions of differing signal intensity correspond to known borders between cortical areas. For example there is a sharp transition in signal intensity at the parietooccipital fissure. Examples of relative signal intensities for several cortical areas are given in Table 1. The signal intensities for corresponding BAs in the two hemispheres were highly correlated (R^2 = 0.82)

Discussion: Mapping of FLAIR signal intensity onto surface representations of the cerebral cortex demonstrates that there are significant regional differences in signal intensity across the cortex. These regional differences are consistent across subjects (Figure 1). Regional differences in signal appear to correspond remarkably well to known landmarks which demarcate different cortical regions. Comparison with surface representation of Brodmann Areas reveals a tight correlation between the FLAIR signal intensity boundaries and Brodmann area boundaries. . FLAIR signal intensity may be able to provide a basis for routinely parcellating the human cortex from MRI data. Because FLAIR combines T1 effects (from inversion), T2 effects from a long TE as well as MT effects from a long echo train, it is not clear the extent to which each of these mechanisms contributes to the differences we have observed. These findings motivate further research to identify the cytoarchitectonic and myeloarchitectonic features which give rise to these variations of FLAIR signal intensity.

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