Assymmetric Brain Development in Children with Sturge-Weber Syndrome Demonstrated by Volumetric MRI

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Introduction: Sturge-Weber syndrome (SWS) is a neurocutaneous disorder characterized by facial port wine stain, glaucoma, and pial angiomatosis involving one cerebral hemisphere in 85% of the cases.[1,2] Hemispheric atrophy and calcifications often develop and can be associated with cognitive impairment. Abnormal brain development is presumptively associated with the impaired cognitive functions. However, very limited data have been reported on the measurement of structural brain development in SWS. In the present cross-sectional study, we measured hemispheric WM and cortical GM volumes, both ipsi- and contralateral to the angioma, on segmented volumetric MRI images of children with unilateral SWS. The goal of the study was to determine and compare age-related changes in GM and WM volumes in the affected versus the contralateral hemisphere.

Materials and Methods: *Subjects.* Twenty-one children (13 girls; age range 1.5 – 10.3 years, mean age 5.3 years) with unilateral SWS and a history of partial seizures have undergone MRI as part of a prospective neuroimaging research study. All MRI studies were carried out on a Sonata 1.5 T MR scanner (Siemens, Erlangen, Germany), using a standard head coil. An axial 3D gradient echo T1 weighted (TR/TE: 20/5.6 ms, flip angle: 25^o, voxel size 1x0.5x2 mm3) scan was acquired for volumetric measurements. A post-gadolinium (0.1 mmol/kg) T1 weighted image was used to identify the leptomeningeal angioma. Children < 7 years old were sedated with nembutal (3 mg/kg), followed by fentanyl (1 µg/kg).

Image Processing. SPM2 was used for image processing. Segmentation of MR image volumes was performed using the maximum likelihood "mixture model." As SPM2 uses, in addition to voxel intensities also GM, WM and CSF probability maps (priors), the image volumes were initially automatically normalized to a custom-made, study-specific pediatric MRI template, then segmented using the priors and the intensity information. Subsequently all images were transformed back into native space using the inverse transformation matrix. As a result, new image volumes in native space were created with voxel values between 0 and 1 representing GM and WM probabilities (Figure 1). Left- and right hemispheric regions (ROIs) were defined in all supratentorial image planes and then overlaid onto the probability images. Cortical GM and hemispheric WM volumes were calculated by multiplying the respective ROI sum with the voxel volume for each hemisphere, ipsi- and contralateral to the angioma.

Statistical Analysis. Initially, an F-test was applied to determine whether changes in GM and WM volume are linear or quadratic with age. In order to test whether changes of GM or WM volumes with age differ between the contralateral and ipsilateral side, a bootstrapping procedure was applied.

Results: *Decreased GM and WM volumes on the side of the angioma.* Both the ipsilateral cortical GM and hemispheric WM volumes were smaller as compared to the side contralateral to the intracranial angioma. For the cortical GM volume, the mean asymmetry between the two hemispheres was 18 ± 16% (mean volume difference 50 cm^3), whereas for the hemispheric WM volume, the mean difference was 20 ± 21% (mean volume difference 24 cm^3).

Correlation between age and GM/WM volumes. Both GM and WM volumes increased monotonically with age (Figure 2A, B), and a linear fit of the data was not significantly different from a quadratic fit for both the ipsilateral and contralateral GM and WM volumes ($p > 0.5$). Age of the patients correlated with contralateral cortical GM volumes ($r = 0.58$; $p = 0.006$) but not with ipsilateral GM volumes ($r = 0.34$; $p = 0.14$). The difference between these correlations was significant ($p = 0.025$). Moreover, the correlation between patient age and hemispheric WM volumes was significant for both the contralateral ($r = 0.90$; $p < 0.001$) and ipsilateral ($r = 0.45$; $p = 0.04$) values. Again, these correlations proved to be highly significantly different ($p = 0.003$).

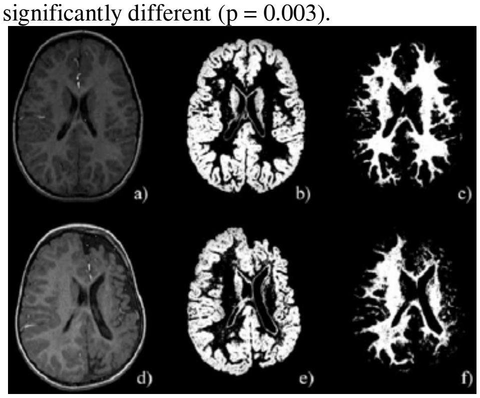

Figure 1.

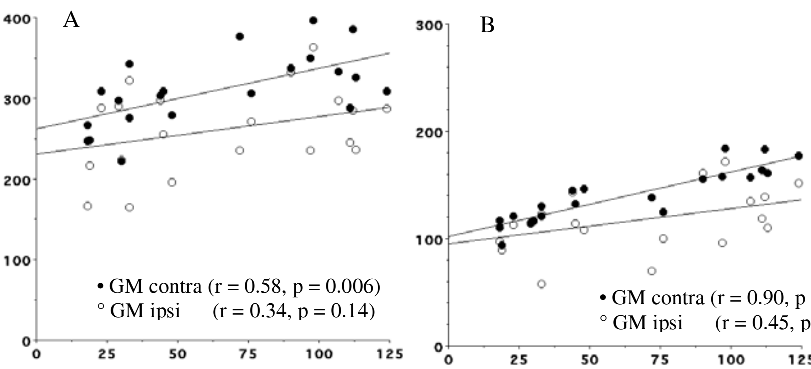

Figure 2.

Discussion and Conclusions: In children with unilateral Sturge-Weber syndrome, although both gray matter and white matter volumes increase with age on the affected side, they both show a progressive volume loss in comparison to the contra-lateral hemisphere. Our findings are in line with previously reported WM abnormalities in early SWS.[3] Furthermore, our data show that, with the progression of the disease, the volume differences of both white matter and gray matter vs. their contralateral sides tend to be bigger, in suggestion of the deterioration of patients' neurological functions. Volume loss of brain tissue in the affected hemisphere, measured by MRI, could serve as an index of the advancement and severity of Sturge-Weber syndrome.

References: 1. Roach ES, Bodensteiner JB. The Sturge-Weber Foundation, Mt Freedom, NJ, 1999;27-38.
2. Benedikt RA, Brown DC, Walker R, et al. AJNR Am J Neuroradiol 1993;14:409-15.
3. Adamsbaum C, Pinton F, Rolland Y, et al. Pediatr Radiol 1996;26:759-62.