Differences in the proportional volume of different brain regions relative to the whole brain size

M. Belke[1], D. H. Salat[2], E. Wehrmann[1], K. Menzler[1], U. Lengler[3], W. H. Oertel[1], F. Rosenow[1], K. Krakow[3], and S. Knake[1]
[1]Department of Neurology, Philipps-University Marburg, Marburg, Germany, [2]Athinoula A. Martinos Center for Biomedical Imaging, Harvard Medical School, Boston, MA, United States, [3]Brain Imaging Center Frankfurt, University of Frankfurt, Frankfurt, Germany

Introduction: Volumetric MRI studies have been widely used to evaluate differences between patient groups and healthy subjects or between men and women. However, little is known about the in vivo size of different brain regions in relation to the total intracranial volume (TIV). The aim of the present study was to evaluate volume differences in certain brain regions in relation to changes in TIV.

Methods: Fifty-two healthy subjects underwent imaging with a 3D T1-weighted high-resolution isometric Magnetization Prepared Rapid Gradient Echo (MP-RAGE) scan on a 3T MRI scanner (Siemens Trio, Siemens Medical Solutions, Erlangen, Germany). The scans were analyzed using FreeSurfer (http://surfer.nmr.mgh.harvard.edu/fswiki). An automated parcellation of the cortex, subcortical (without white matter) and white matter structures was performed and the TIV was calculated. Based on these parcellations a slope, describing the correlation between the volume of the respective structure and the TIV was calculated using the regress function in Matlab (Matlab 7.6.0.324 (R2008a)) (Figure 1). This slope may be used to calculate the normalized volumes of each parcellation by using the formula (Buckner 2004):

$HCV_{adj} = HCV_{nat} - b(TIV_{nat} - Mean\ TIV_{nat})$ (1)

HCV_{adj} is the covariance-adjusted (corrected) volume, HCV_{nat} is the structure volume in native space, b is the slope of the volume regression on TIV_{nat}. TIV_{nat} is the total intercranial volume and Mean TIV_{nat} is the sample mean of the TIV_{nat}.

An unpaired t-test was performed to investigate sex differences of the original and the native brains.

Results: The volumes of cerebral white matter and the cerebral cortex (slope 0.16-0.18) showed the highest correlation with TIV, followed by the cerebellar cortex (slope 0.021-0.024). Of the subcortical structures the brainstem volume had the highest correlation with TIV (slope 0.012). Other subcortical structures did not show any relevant increase in volume with increasing TIV (slopes 0.0008-0.0039). The size of the corpus callosum was relatively stable (slope 0.00019-0.00033). Within the ventricular system only the lateral ventricles were growing with increasing TIV (slope 0.005-0.006). The volume of third and fourth ventricle did not differ depending on different TIV. Figure 2 shows the slopes of the cortical parcellation projected on the average brain of the study.

Although there were substantial differences between men and women in uncorrected brain volumes, no region (cortex, subcortical structures and white matter) showed any differences after normalization and after using the described procedure correcting for TIV.

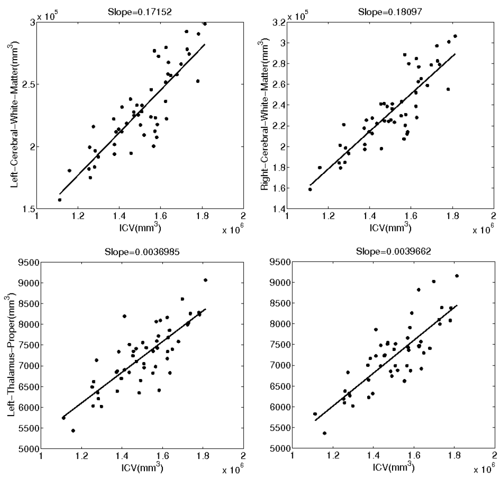

Figure 1: Sample slopes between brain structures and TIV.

Discussion: These data demonstrate that the relative size of certain brain regions varies depending on the TIV: The cerebral white matter and the cerebral cortex showed the most significant scaling with TIV. Additionally, we could show that no sex differences are apparent when correcting for TIV. These results implicate that future studies investigating volumetric changes need to adjust for possible differences in whole brain volume, especially if patient groups are investigated that might be especially prone to changes in TIV. Our results provide normative estimates of scaling that can be used in other studies to adjust for head size in future.

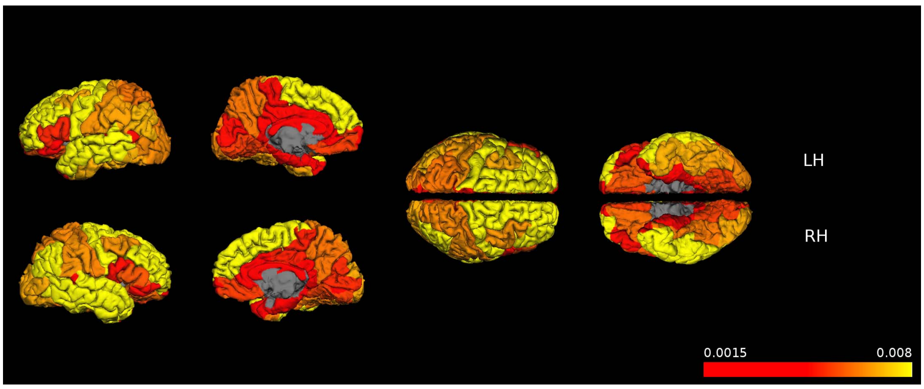

Figure 2: The slopes of the cortical parcellation projected on the average brain of the study