Semi-automatic Brain Ventricle Segmentation using Partial Volume Fraction Calculation of CSF based on Quantitative MRI

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Introduction. The determination of the size of the brains ventricle system is important for investigating diseases such as hydroencephaly and dementia. It is, however, notoriously difficult to perform and it typically requires multiple contrast images with both high resolution and high SNR (see e.g. [1-3]). The main problem is that MR images are arbitrarily scaled, that tissue contrast depends on the actual scanner settings and that contrast may even be non-uniform across the image. A far more robust approach is to quantify the physical parameters responsible for the image intensity, namely the R1 relaxation rate, the R2 relaxation rate and Proton Density that directly represent the underlying tissue, independent of the scanner settings and imperfections. Using R1, R2 and PD as coordinates in a R1-R2-PD space voxels with Cerebrospinal Fluid form a cluster that differs from the Grey Matter and the White Matter data clusters. Partial volume fraction can be estimated from the geometrical position between these clusters. A major advantage of this method is that it does not involve user-dependent thresholding between tissues, it performs accurately independent of image resolution and it is based on a single scan, thereby avoiding image registration.

Methods. The quantification sequence used was a multi-echo saturation recovery sequence using a repetition time TR = 3.2 s, 6 echoes at multiples of 15 ms and saturation delays of 128, 384, 1408 and 3072 ms [4]. Ten healthy volunteers (age 22-38 years) were scanned at six different in-plane resolutions between 1.0 to 2.0 mm with incremental steps of 0.2 mm. The slice thickness was 5 mm, 25 slices were acquired in a scan time of 6 minutes for 1 mm down to 3 minutes for 2 mm in-plane resolution. The scanner was a 1.5T Philips Achieva (PMS, Best, The Netherlands). Data was analyzed using SyMRI Suite (SyntheticMR AB , Sweden).
Bloch simulations were used to calculate the expected R1-R2-PD values at each possible partial volume combination. Two separate CSF partial volume maps were calculated with CSF towards GM and CSF towards WM, respectively. The probability of the nearest neighbors of being GM or WM was used as a weight when merging these two maps resulting in a CSF partial volume map applicable on the whole brain. A roughly drawn manual region of interest was used to select the ventricular area.

Results. The total CSF volume in the intracranial space ranged between 92 and 163 mL and had the same value for all resolutions with an average standard deviation of 2.4 mL, max 2.8 ml. The total ventricular volume ranged between 21.3 and 28.8 mL and had the same value for all resolutions with an average standard deviation of 0.3 mL, max 0.4 mL.

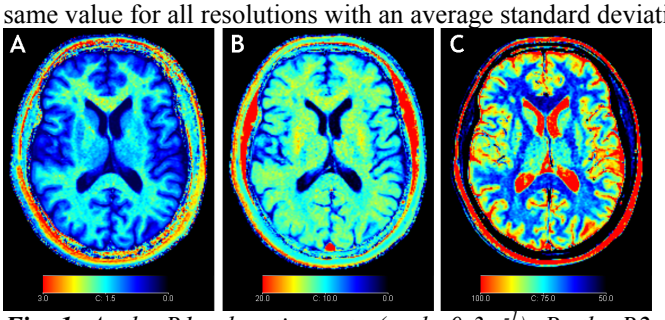
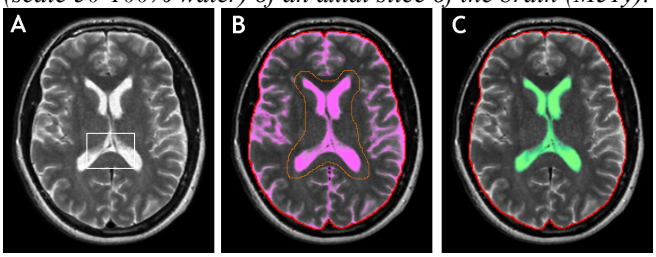


Fig. 1. *A: the R1 relaxation rate (scale 0-3 s^{-1}), B: the R2 relaxation rate (scale 0-20 s^{-1}) and C: the Proton Density (scale 50-100% water) of an axial slice of the brain (M51y).*



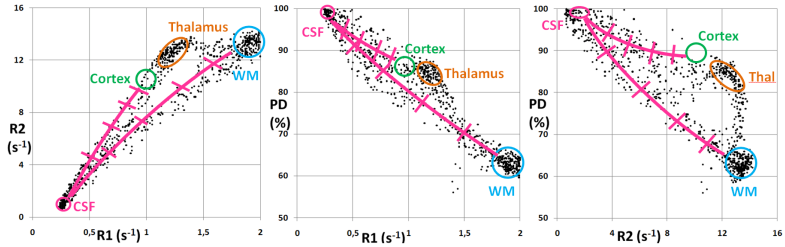


Fig. 2. *R1-R2, R1-PD and R2-PD projections of data of the ROI in Fig. 3A. The reference clusters position of cerebrospinal fluid (CSF), cortex, thalamus and white matter (WM) are indicated. The lines are the predicted R1-R2-PD values caused by partial volume effects when changing from one tissue to the other. The scale marks indicate a change of 20% partial volume.*

Fig. 3. *A: A T2W image synthesized from the R1, R2 and PD data, B: the T2W image with an automatically traced red contour around the intracranial volume and a partial volume calculation of CSF drawn in purple. A rough manually drawn region of interest is drawn to indicate the lateral ventricles. C: The segmented ventricle in green.*

Conclusion

Partial volume calculation of CSF based on a quantitative R1, R2 and PD measurement allows an accurately estimation of the total amount of CSF and the total ventricular volume in the intracranial cavity, independent of image resolution or intensity thresholding.

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