Brain tissue water content measured by MRI: pre- vs. post-shunt chronic hydrocephalus

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Introduction: Hydrocephalus is due to blockage in cerebrospinal fluid (CSF) flow which results in a dilated brain ventricular system. Brain water content measurements have been used clinically to detect brain disorders and the pattern in water content depends largely on the specific pathology. Understanding the water distribution before and after shunting is required in quantitatively describing the physiology of hydrocephalus. The measurements of the brain tissue water content were performed on acute hydrocephalus in previous studies[1]. However, the date from chronic hydrocephalus is lacking. In this study, a MRI inversion recovery fast spin echo (FSE) imaging with time-efficient slice ordering (TESO-IRFSE) T1 method [2] has been used to non-invasively measure the absolute brain tissue water content in both (pre- and post-shunt) chronic hydrocephalus and healthy subjects. A statistical comparison has been performed between patients and control group and pre and post shunting patients as well.

Methods: A total of 12 subjects (six healthy volunteers and six hydrocephalic patients) have participated in this study. All MR images used to generate the T1 maps were acquired on a GE Signa 3T MR scanner (GE Medical Systems, Milwaukee, WI) using a standard quadrature bird-cage head coil and TESO-IRFSE pulse sequence. The parameters for the MR protocol were: matrix size = 256 x 128, slice thickness = 4 mm, slice spacing = 4 mm, FOV = 240 mm, TE = 8.1 ms, echo spacing = 8.1 ms, TR = 3 s, 6 different time of inversion conditions for each slice, total 12 slices were collected. At various magnetic field, the inverse of the tissue water fraction by weight fw and the inverse of T1 have a clear linear relationship of $(1/f\text{w}) = A+B(1/T1)$, where A=0.926 and B=0.374 at 3T [2,3]. The brain water content map (H_2O map) was calculated based on T1 map. Two-tailed student t test was applied to water content in selected gray and white matter ROIs at the periventricular region and comparisons with a $p < 0.05$ was considered statistically significant.

Results and discussion: The brain water content of selected regions of interest (ROIs) is shown in Table 1 and Figure 1. The brain water content was significantly higher in all regions in the hydrocephalic patients except for the grey matter of the putamen and head of caudate. For the patients who underwent a shunting operation, an increase in water content occurred at genu and splenium of the corpus callosum. Little change was seen in the frontal and posterior white matter, and only a small trend of decreasing water content was seen in grey matter. These results are consistent with Hakim's hypothesis that water reenters the white matter, reduces the ventricles and expands the periventricular tissue after shunting [4]. It should be noted that all these patients had chronic hydrocephalus and the changes in brain size were small after shunting. In acute hydrocephalus, greater brain size change are seen when the ventricles size changes are larger [1].

Conclusion: Absolute brain tissue water content measurement based on TESO-IRFSE technique takes advantage of the excellent image quality of spin echo acquisition, which is less prone to susceptibility artifacts that are often found in gradient echo acquisition. High quality and high-resolution brain T1 maps facilitate accurate brain water content measurements in hydrocephalic patients. Understanding the details of water shift before and after shunting will shed a light on the physiology of hydrocephalus.

Table 1. Water content comparison between hydrocephalus patients and healthy volunteers.

	Frontal white matter	Posterior white matter	Genu of corpus callosum	Splenium of corpus callosum	Head of caudate nucleus	Putamen	Thalamus
Health volunteers (weight %)	68.5 ± 0.7	69.3 ± 0.7	67.2 ± 1.0	67.9 ± 0.6	79.1 ± 1.1	77.4 ± 1.2	75.1± 0.8
Patients (weight %)	70.1 ± 1.0	71.6 ± 0.5	69.3 ± 0.8	70.7 ± 1.7	79.2 ± 0.8	78.2 ± 0.6	76.1 ± 0.3
P (t-test)	0.01	0.00006	0.002	0.01	0.8	0.14	0.02

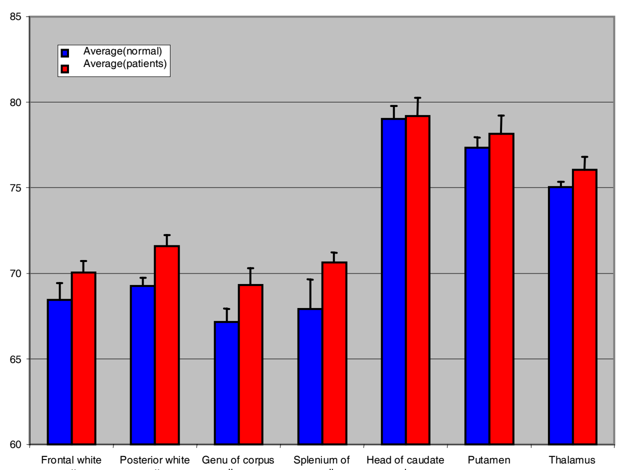

Figure 1. Comparison of brain water contents in healthy volunteers and in hydrocephalic patients.

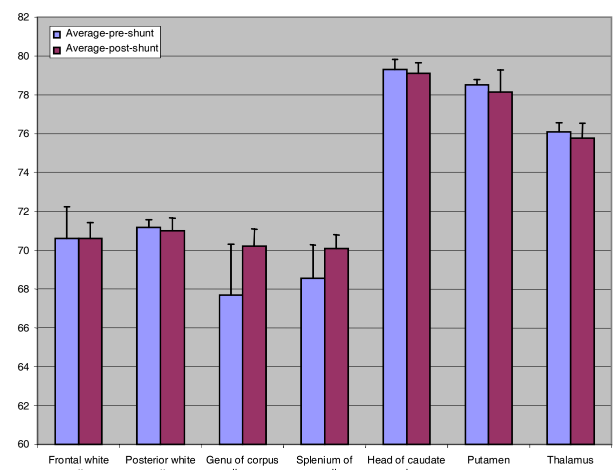

Figure 2. Comparison of brain water contents before and after shunting.

References: [1] Penn RD et al.(1984) Neurosurgery 14:670-675. [2] Zhu D.C. et al.(2005) MRM 54:725-731. [3] Fatouros PP et al.(1999) J Neurosurgery 90:109-115. [4] Hakim s et al.(1976) Surg Neurol 5: 187-210.